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1 Summary

Sea Ice Index images depict ice cover and trends in ice cover in the Arctic and Antarctic oceans. Sea Ice Index data files tabulate ice extent in numbers. The images and data are produced in a consistent way that makes the Index time-series appropriate for use when looking at long-term trends in sea ice cover. Both monthly and daily products are available. However, monthly products are better to use for long-term trend analysis because errors in the daily product tend to be averaged out in the monthly product and because day-to-day variations are often the result of short-term weather.

Sea Ice Index products are derived from two data sets: the Near-Real-Time DMSP SSMIS Daily Polar Gridded Sea Ice Concentrations, referred to in this document as the NRTSI product, and the Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-SSMIS Passive Microwave Data, referred to in this document as the GSFC product. These satellite passive microwave-derived data sets are used to generate the daily and monthly images and numbers that comprise the Sea Ice Index record of sea ice extent and concentration from November 1978 to present. Information on the accuracy and precision of passive microwave-derived sea ice concentration products can be found in this documentation as well as in the documentation for the NRTSI and GSFC products.

Monthly images show sea ice extent with an outline of the median extent for that month for comparison. Other monthly images show sea ice concentration as well as trends and anomalies in concentration for that month. Monthly extent products are also available as geographic information systems (GIS) compatible shapefiles. Comma delimited ASCII text data files contain monthly mean extent and area, in millions of square kilometers, by year. These monthly extent numbers are used for graphs of extent anomalies with trend lines and significance intervals. Anomalies and median extent are calculated using a 30-year reference period of 1981 through 2010.

Daily images show sea ice extent, with an outline of the median extent for that day for comparison, and sea ice concentration. Comma delimited ASCII text data files contain daily extent, in millions of square kilometers, for almost every day from 1978 onward. These daily extent numbers are used for graphs of daily extent over the last four months. The daily products are good for tracking the seasonal growth and retreat of ice, but there are more accurate views of sea ice on any given day. For example, the Multisensor Analyzed Sea Ice Extent (MASIE) products show daily extent at 4 km resolution and are distributed in partnership with the operational National Ice Center (NIC). For more information about current conditions and their significance, see Arctic Sea Ice News and Analysis.

2 Overview of Sea Ice Index Processing

2.1 Introduction

Records of sea ice extent and concentration from satellite passive microwave brightness temperature data are available beginning in October 1978 with the Nimbus-7 Scanning Multichannel Microwave Radiometer (SMMR); and, since July 1987, from a series of Special Sensor Microwave Imager (SSM/I) and Special Sensor Microwave Imager/Sounder (SSMIS) instruments on Defense Meteorological Satellite Program (DMSP) satellites. Sea ice concentration can be estimated from brightness temperature data because sea ice and water have differing passive microwave brightness temperature signatures. For example, water has a highly polarized signature within a certain frequency band, that is, its brightness temperature in the vertical channel is higher than that in the horizontal, while sea ice does not. Most algorithms use some form of a polarization difference or ratio and a linear mixing formula with brightness temperature tie points to estimate the concentration of sea ice within the field of view (FOV) of the sensor. The Sea Ice Index is based on the NASA Team algorithm (Cavalieri et al. 1997).

2.2 Mean Concentration Fields and Median Ice Edge Position

On monthly extent images, ice ends and water begins where the concentration estimates of grid cells in the gridded average, or mean, concentration field for that month drop below 15 percent. To compare this edge position with what is typical for the month, we computed a median edge for the month using those grid cells for which there is a 50 percent probability of ice occurring at 15 percent concentration or greater based on the January 1981 to December 2010 portion of the data set. This appears as a pink line in the monthly extent images. Alternatively, we could have computed a climatological edge by averaging the 30 mean concentration fields for that month between 1981 and 2010, and using the 15 percent cutoff in the average concentration image as the climatological edge. However, this method results in an average or mean edge that is unlikely to resemble any typical ice edge, because the location of the edge varies considerably from year to year. The median is a more meaningful representation, so that is used for the Sea Ice Index estimated edge position.

On daily extent images, the same method was used to calculate the median ice edge position for each day of the year, using the same base period. This appears as an orange line in the daily extent images.

2.3 Data Sources

The Sea Ice Index time series is split into two sections: *near-real-time* and *final*. The near-real-time section is comprised of the most recent data available and is created from the Near-Real-Time DMSP SSMIS Daily Polar Gridded Sea Ice Concentrations (NRTSI product) that is produced at and distributed from NSIDC, with data set ID NSIDC-0081. The final section comprises data from the beginning of the record up to the most recent processing of the Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-SSMIS Passive Microwave Data (GSFC product) that is produced at the Goddard Space Flight Center (GSFC) and distributed from NSIDC, with data set ID NSIDC-0051.

The reason for splitting the Sea Ice Index into near-real-time and final sections is that the GSFC product is more tightly quality controlled; and for this reason, NSIDC considers it the *final* authoritative SMMR, SSM/I, and SSMIS passive microwave sea ice concentration record. However, NSIDC does not receive this product from GSFC until roughly a year after the data are acquired. Therefore, we use the near-real-time NRTSI product to fill the gap until the final GSFC

product is available. NRTSI data are processed at NSIDC as closely as possible to the way the GSFC data are processed at Goddard, but the brightness temperature data source for the two products is different along with other small differences. For more information, see the Consistency of the Data Record section of this document.

The GSFC product covers all but the last 6 to 18 months of data, and the NRTSI product is used to extend the record to present. The Data Sources section of this document provides further details.

These source data sets are created using the NASA Team algorithm (Cavalieri et al. 1997) which converts brightness temperatures to gridded ice concentration estimates. For more information, see the NASA Team Sea Ice Algorithm document on the NSIDC Web site. The documentation for the GSFC product and the NRTSI product have more information on differences in the processing of the two products, along with information on instruments, data acquisition methods, and derivation techniques used. See the following documents:

- Near-Real-Time DMSP SSMIS Daily Polar Gridded Sea Ice Concentrations (NRTSI product)
- Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-SSMIS Passive Microwave Data (GSFC product)

Sea Ice Index code runs every day to make the daily products using the NRTSI product. For the monthly products, the code runs once a month, a few days after the end of the month. When GSFC data become available, NSIDC runs the Index processing code to reprocess the NRTSI version with the GSFC version. The `data_type` column in the Monthly Sea Ice Extent and Area Data Files indicates the source of that row's extent and area. In the Daily Sea Ice Extent Data Files, the GSFC product ends about a year ago and the NRTSI product takes up where the GSFC stopped.

2.4 Instrument Description

The GSFC and NRTSI product data come from the Scanning Multi-channel Microwave Radiometer (SMMR) instrument on the Nimbus-7 platform and from a series of Special Sensor Microwave Imager (SSM/I) and Special Sensor Microwave Imager/Sounder (SSMIS) instruments on the Defense Meteorological Satellite Program (DMSP) satellites. Table 1 lists the satellite platform and instrument along with the time period over which brightness temperatures from that instrument were used in the processing of the input GSFC product and the NRTSI product.

Table 1. Usage Period for Each Instrument

Platform and Instrument	Time Period
Nimbus-7 SMMR	26 October 1978 - 20 August 1987
DMSP-F8 SSM/I	21 August 1987 - 18 December 1991
DMSP-F11 SSM/I	19 December 1991 - 29 September 1995
DMSP-F13 SSM/I	30 September 1995 - 31 December 2007
DMSP-F17 SSMIS	01 January 2008 - 31 March 2016
DMSP-F18 SSMIS	01 April 2016 - present

For a complete description of each sensor, see the following links:

- Scanning Multi-channel Microwave Radiometer (SMMR)
- Special Sensor Microwave Imager (SSM/I)
- Special Sensor Microwave Imager/Sounder (SSMIS)

For more information on the DMSP suite of satellites see the Defense Meteorological Satellite Program (DMSP) Satellite F17 Web page.

2.5 Overview of Processing Steps

The Sea Ice Index Daily Product Processing flow chart (Figure 1) and the Monthly Product Processing flow charts (Figures 2, 3, and 4) illustrate the full processing sequence (To see full resolution versions see Appendix 1: Data Flow Diagrams). Green blocks are Sea Ice Index data files that can be downloaded. The data set IDs correspond to the following NSIDC data sets:

- NSIDC-0001: DMSP SSM/I-SSMIS Daily Polar Gridded Brightness Temperatures
- NSIDC-0080: Near-Real-Time DMSP SSMIS Daily Polar Gridded Brightness Temperatures
- NSIDC-0051: Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-SSMIS Passive Microwave Data (GSFC product)
- NSIDC-0081: Near-Real-Time DMSP SSMIS Daily Polar Gridded Sea Ice Concentrations (NRTSI product)

The equivalent Sea Ice Index NSIDC data set ID number is G02135. For in-depth processing details for each product, see Section 3: Detailed Data Description.

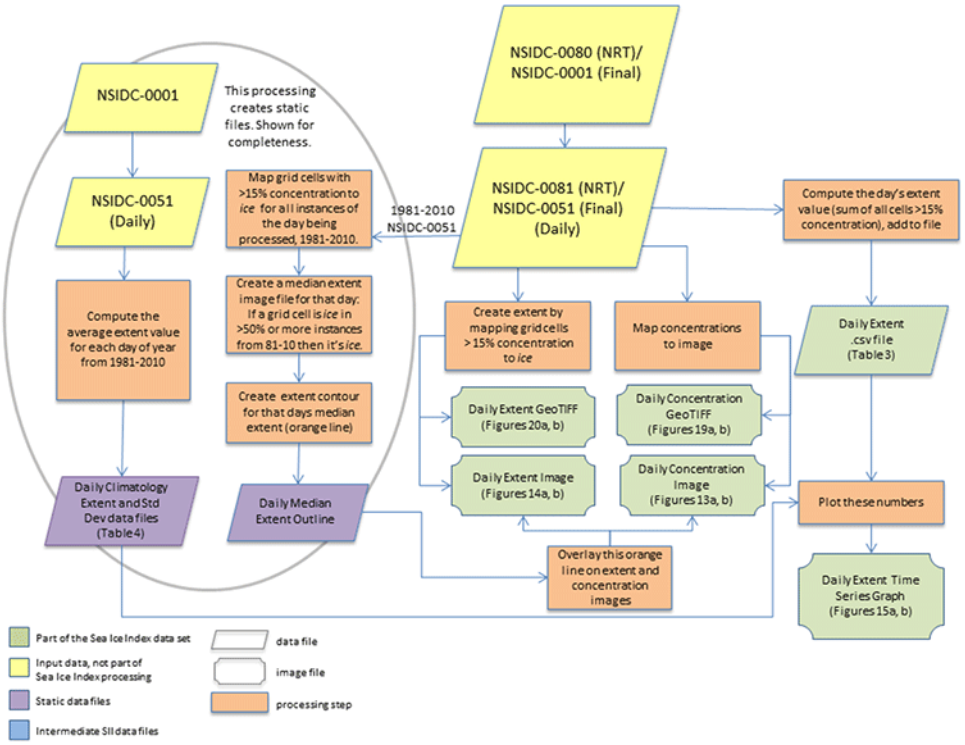


Figure 1. Sea Ice Index Daily Product Processing Flow Chart.

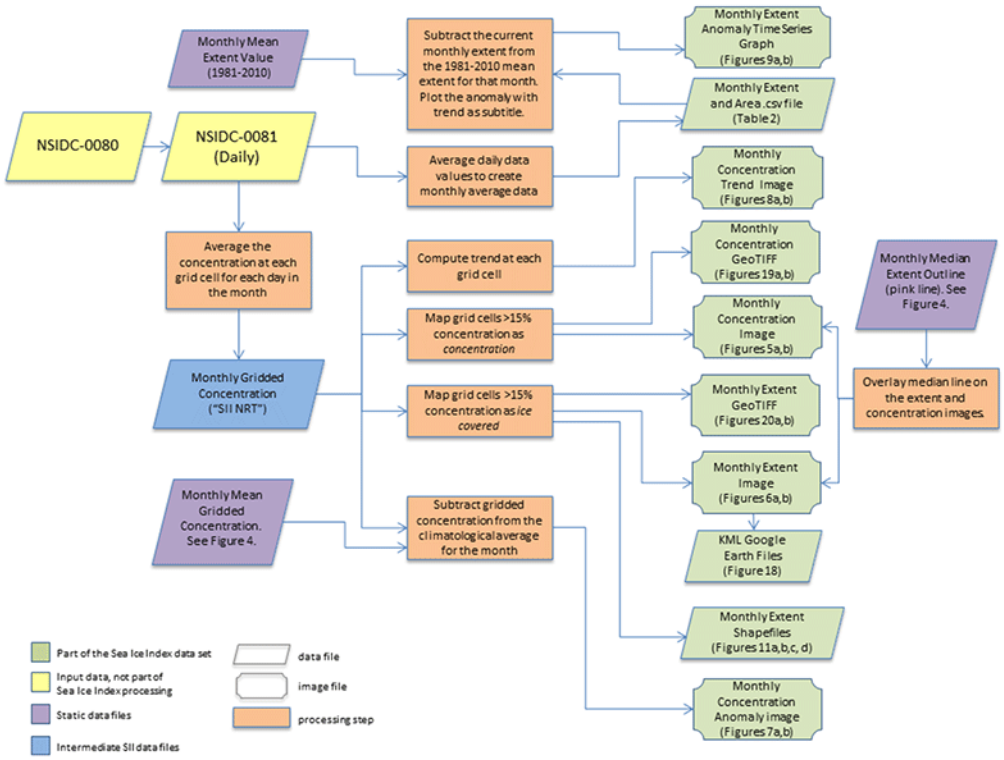


Figure 2. Sea Ice Index Monthly Product Processing Using NRTSI Product.

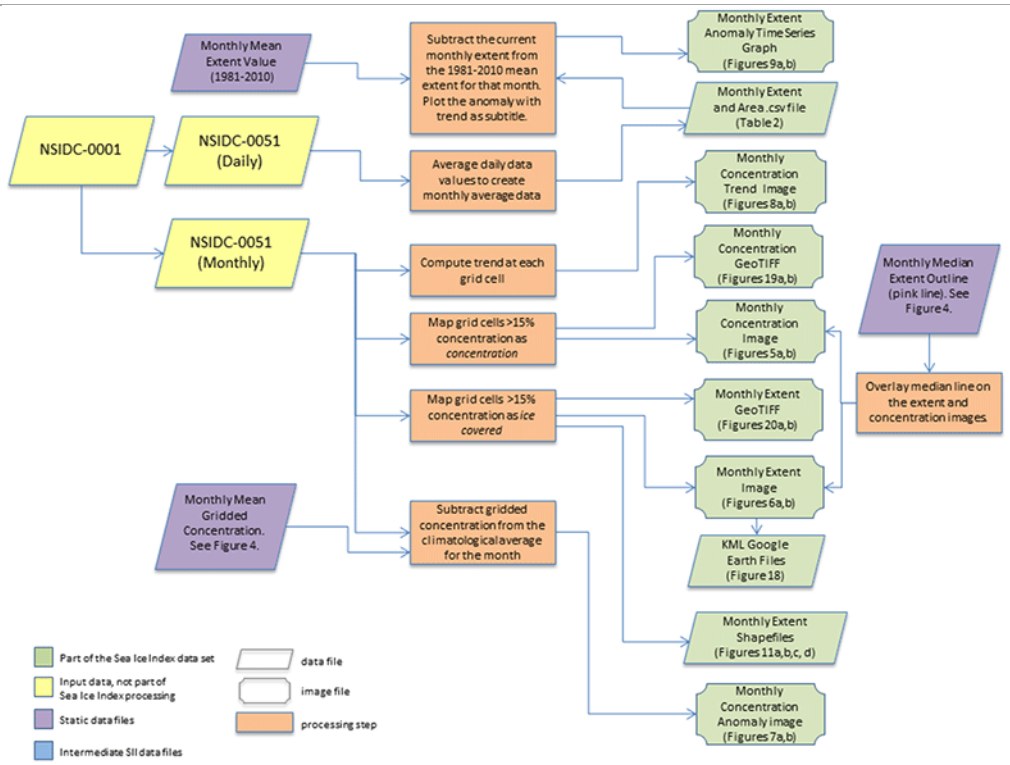


Figure 3. Sea Ice Index Monthly Product Processing Using GSFC Product.

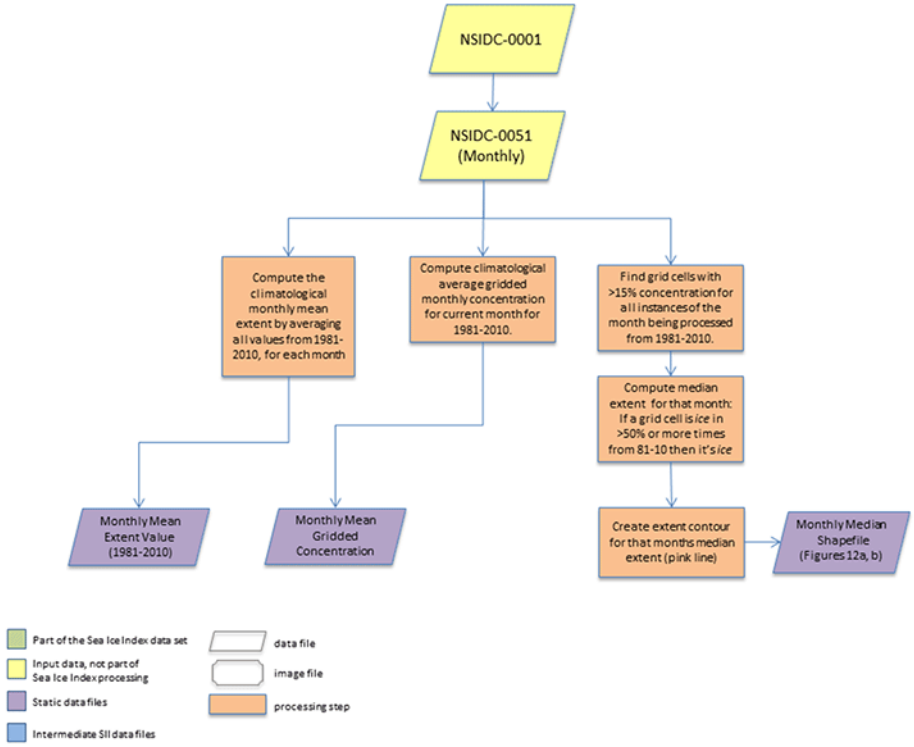


Figure 4. Sea Ice Index Processing for 1981-2010 Median and Means.

3 Detailed Data Description

This section describes each image and data file in detail including a file description, file format, file naming convention, processing steps that NSIDC takes to create the file, and directions on how to access the file.

Use the following list to navigate this section:

- Monthly Images and Data Files
- Monthly Shapefiles
- Daily Image and Data Files
- Google Earth Files
- GeoTIFF Files

3.1 Monthly Images and Data Files

These images and data files present ice extent and area averaged over a month. For near-real-time data, as each month concludes, NSIDC runs a processing script that first creates a monthly average gridded concentration field from the daily gridded NRTSI field. That, in turn, is used to make the sea ice concentration and extent images and to arrive at that month's ice extent and ice area numbers. When the GSFC product becomes available, we run the processing script again to create the *final* Sea Ice Index product. For a discussion on the difference between extent and area, see the Frequently Asked Questions on the Arctic Sea Ice Web page: What is the difference between sea ice area and extent?

As described in Data Sources section, the Sea Ice Index time series is split into two sections: near-real-time and final. Each image contains a label on the left hand side with either the words *near-real-time data* or *final data* to indicate the source of the data either the Near-Real-Time DMSP SSMIS Daily Polar Gridded Sea Ice Concentrations (NRTSI product, NSIDC-0081) or the Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-SSMIS Passive Microwave Data (GSFC product, NSIDC-0051), respectively. The most recent images and data values, for about the last 6 to 18 months, are from the NRTSI product. Older images and data values are from the GSFC product.

All monthly images are provided in PNG format (`.png`), and data files are in comma delimited ASCII text format (`.csv`). See each section below for specifics about that file.

- Monthly Sea Ice Concentration Images
- Monthly Sea Ice Extent Images
- Monthly Sea Ice Concentration Anomaly Images
- Monthly Sea Ice Concentration Trend Images
- Monthly Sea Ice Extent Anomaly Graphs
- Monthly Sea Ice Extent and Area Data Files

3.1.1 Monthly Sea Ice Concentration Images

The monthly concentration images, like those in Figures 5a-d, show a particular month's ice concentration with each 25 km data cell color-coded in shades of blue to white, where dark blue is zero percent ice (open ocean) and white is 100 percent ice. There is an area around the North Pole that is not imaged by the satellite it is referred to in this document as the Arctic Pole Hole. There is no way to know what the actual concentration is within this area, so the area is left out of the images (dark gray circle). See Table 8 for the sizes of the Arctic pole holes through time.

File Naming Convention

`h_yyyymm_conc_[blmrbl]_[hires]_vX.x.png`

See Table 9 for a description of the naming convention variables.

Processing Steps

1. **Obtain gridded input data.**
   Processing begins with ice concentration data in the form of arrays, or gridded fields. The near-real-time monthly concentration images are constructed from the *daily* Near-Real-Time DMSP SSMIS Daily Polar Gridded Sea Ice Concentrations (NRTSI product). The final monthly concentration images are constructed from the *monthly* portion of the Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-SSMIS Passive Microwave Data (GSFC product) because the GSFC product contains a monthly averaged version and the NRTSI product does not.
2. **Derive gridded monthly mean concentration fields.**
   Note: Be aware that in constructing monthly mean ice concentrations, a temporal and spatial average are conflated. That is, a mean concentration of 50 percent for a particular grid cell for the month of September could be the result of 100 percent concentration at that location for 15 days and 0 percent concentration for 15 days, or 50 percent concentration for 30 days, or some other combination. The meaning of average concentration can therefore be ambiguous, especially near the ice edge, where wind can move ice rapidly into and out of the area covered by a grid cell or when the ice edge is melting or growing quickly.

   NSIDC constructs a month's near-real-time mean concentration field from the daily NRTSI product mentioned in step 1. To do this, the record of daily concentration at each grid cell is averaged to produce an *intermediate* Sea Ice Index version of the monthly gridded ice concentrations (blue box in Figure 2), This is termed an intermediate product because it is used only for Sea Ice Index processing. Then, a threshold value of 15 percent is used as a cut off for the lowest ice concentration because data values less than 15 percent from passive microwave instruments are too uncertain to use. Therefore, values less than 15 percent are considered to be 0 percent ice and are colored dark blue in the images. All other concentrations are between 15 percent and 100 percent and are colored in different shades of blue to white. Occasionally, data from one or more days within the month are missing for a given 25 km grid cell. Monthly averages are computed from the daily product data for that cell only if there are at least 20 days of data for that cell. Otherwise, the cell is labeled as missing (colored yellow in the images).

   NSIDC constructs a month's final mean concentration field from the monthly gridded GSFC product mentioned in step 1. Then, the 15 percent cutoff is applied. Occasionally, values greater than 100 percent are present in the input data; these are considered to be 100 percent ice and are colored white in the images.

   Note that there may be small differences in the monthly mean concentration grids from the NRTSI product and

those from the GSFC product that later replace them. These result from differences in processing discussed in the Additional Information on Source Data, Processing, Algorithms, and Accuracy section of this document.

3. **Compute sea ice area.**
   The area in the bottom margin of the ice concentration image is the sum of the area covered by ice. For a description of how this is computed, see processing Step 3: Compute the sea ice area under Monthly Sea Ice Extent and Area Data Files.

   Note: The area value is always less than the extent value because extent includes the entire expanse within the ice edge and includes the area under the Arctic Pole Hole, while area takes ice concentration within that edge into account and excludes the area under the Arctic pole hole. For a complete discussion on the difference between extent and area, see the Frequently Asked Questions on Arctic Sea Ice Web page: What is the difference between sea ice area and extent?

4. **Create image from data grids.**
   Sea Ice Index processing maps the monthly concentration fields from the NRTSI and GSFC products as a color-coded image, with a color bar in 10 percent increments in shades of blue to white to indicate concentration. From 0 to 15 percent, the color bar is dark blue to indicate open ocean. Subtle changes in shade are probably not significant; and missing sea ice concentration data, whether for a region or an individual cell appears as yellow dots or areas in the image. The Arctic pole hole is dark gray. The input source is noted in the bottom left-hand corner of the image. The median ice edge for that month, shown in pink, is also added to the image.

   Note: Many missing pixels often fall on areas of open ocean and do not affect extent and area calculations.

Access Files

Access the monthly concentration images: North and South. Then choose a month from the list of directories labeled by a 2-digit and 3-character month abbreviation and look for files named like those in the convention described above.

Sample Images

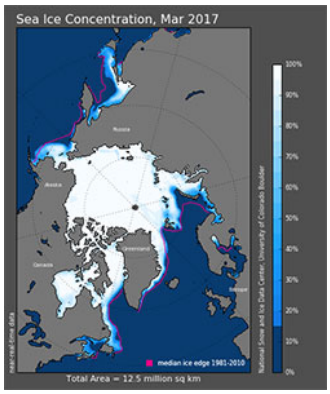


Figure 5a. Monthly Sea Ice Concentration Image for the Northern Hemisphere. Note: The dark gray circle in the center is the SSM/I Arctic pole hole.

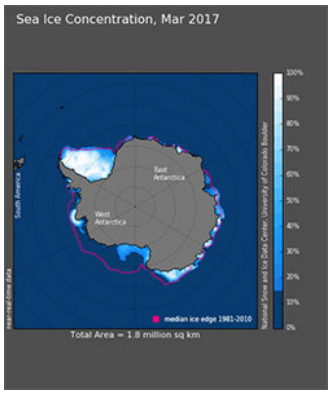


Figure 5b. Monthly Sea Ice Concentration Image for the Southern Hemisphere.

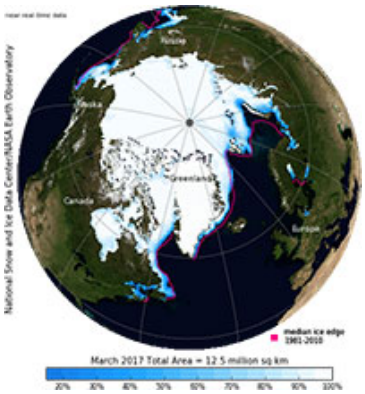


Figure 5c. Blue Marble Version of the Monthly Sea Ice Concentration Image for the Northern Hemisphere.

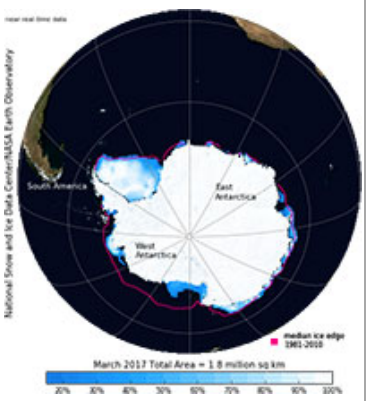


Figure 5d. Blue Marble Version of the Monthly Sea Ice Concentration Image for the Southern Hemisphere.

3.1.2 Monthly Sea Ice Extent Images

The monthly extent images, like those in Figures 6a-d, show the expanse covered by ice at greater than 15 percent monthly mean concentration for both the Arctic and Antarctic. The median line (in pink) shows a typical ice extent for that month, based on a 30-year climatology from 1981 to 2010. We assume that the area around the North Pole that the satellite does not image, the Arctic Pole Hole, is covered by ice at greater than 15 percent concentration; so it is shown as ice-covered in extent images. See Table 8 for the sizes of the Arctic pole holes through time. **Note:** Monthly extent is a better measure of conditions from year to year than is daily ice extent; thus, when doing climatological studies, use the monthly data.

File Naming Convention

`h_yyyymm_extn_[blmrbl]_[hires]_vX.x.png`

See Table 9 for a description of the naming convention variables.

Processing Steps

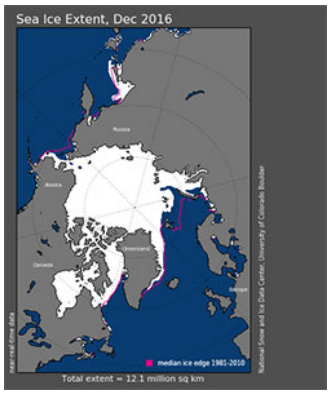
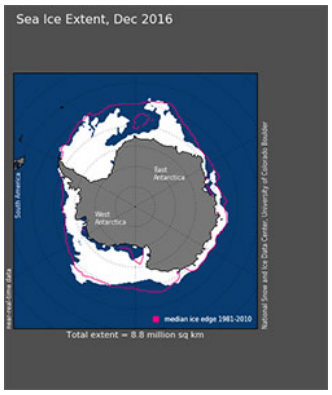
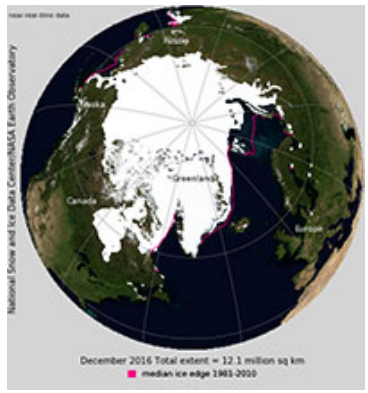
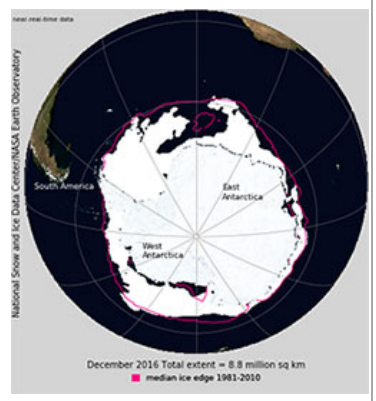
1. **Obtain gridded input data.**
   Obtain the monthly gridded concentration field for the month just completed. See the Monthly Sea Ice Concentration Images section of this document for a description of how these gridded concentrations are created.
2. **Determine extent from concentration**.
   The extent is mapped by taking any cell with a concentration of 15 percent or greater and labeling that cell as ice (colored white in the images).
3. **Compute extent.**
   For a description of how the extent number in the bottom margin of the image is computed, see the Monthly Sea Ice Extent and Area Data Files section of this document.
4. **Overlay the month's median ice edge position.**
   The monthly median ice edge (pink line) is where median concentration, based on the January 1981 to December 2010 portion of the data set, drops below 15 percent. One way to think of this is that, within the pink line, there is a greater than 50 percent probability of ice being present for that month; while outside the line, the probability is less than 50 percent, based on conditions from 1981 through 2010.

   This line is provided as a quick visual comparison with the most recent month's mean ice extent. For more information about the median ice edge, see the Mean Concentration Fields and Median Ice Edge Position section of this document.
5. **Create image from data.**
   Areas labeled as ice are colored white, ocean is dark blue, and land is gray. The median ice edge for that month, shown in pink, is also added to the image.

Access Files

Access the monthly extent images: North and South. Then choose a month from the list of directories labeled by a 2-digit and 3-character month abbreviation and look for files named like those in the convention described above.

Sample Images

 **Figure 6a. Monthly Sea Ice Extent Image for the Northern Hemisphere.**	 **Figure 6b. Monthly Sea Ice Extent Image for the Southern Hemisphere.**	 **Figure 6c. Blue Marble Version of the Monthly Sea Ice Extent Image for the Northern Hemisphere.**	 **Figure 6d. Blue Marble Version of the Monthly Sea Ice Extent Image for the Southern Hemisphere.**

3.1.3 Monthly Sea Ice Concentration Anomaly Images

These images of anomalies in ice concentration, like those in Figures 7a and 7b, show, in percent, how much the ice concentration for the month differs from the mean calculated for that month over the 1981 to 2010 time range. The total anomalous area of sea ice for that month is also shown in the bottom margin of the image. The SMMR Arctic Pole Hole appears on the Arctic images (large light gray circle seen in Figure 7a) because the average concentration is derived over a period that includes SMMR data so the largest hole must be used for the calculations for continuity.

Note: These images should be used with caution because the accuracy of passive microwave derived sea ice concentration is not good when taken over the relatively small area of a grid cell (Fetterer 2002). What appear to be large anomalies near the ice edge are often simply artifacts of the movement of the ice edge.

File Naming Convention

`h_yyyymm_anom_[hires]_vX.x.png`

See Table 9 for a description of the naming convention variables.

Processing Steps

1. **Obtain gridded input data.**
   The input data for these images are monthly mean concentration fields and monthly climatological fields from 1981 to 2010. The monthly concentration data are described in the Monthly Sea Ice Concentration Images section of this document, and the monthly climatological fields are described below.

2. **Derive monthly climatology gridded fields.**
   These are created by averaging the monthly concentrations for a given month from 1981 to 2010. This is done for all twelve months.
3. **Derive concentration anomalies.**
   To produce the concentration anomaly images, the monthly climatology gridded fields for the month in question are subtracted from the monthly sea ice concentration data. The result is a gridded field of concentration anomalies.
4. **Determine total anomalous area.**
   The total anomalous area is computed by taking the value of the concentration anomaly at each grid cell and multiplying that number by the area of that grid cell and then summing that value from all grid cells together.
5. **Create image from data.**
   The gridded concentration anomalies are mapped to shades of red (for positive concentration anomalies) or blue (for negative concentration anomalies). If the computed trend is not significant to within a 95 percent confidence interval, the grid cell is shown as white. The total anomalous area, in millions of sq km, is printed in the bottom margin of the image. **Note:** An area may have a positive anomaly for a given month while at the same time showing a negative trend in concentration over time.

Access Files

Access the monthly anomaly images: North and South. Then choose a month from the list of directories labeled by a 2-digit and 3-character month abbreviation and look for files named like those in the convention described above.

Sample Images

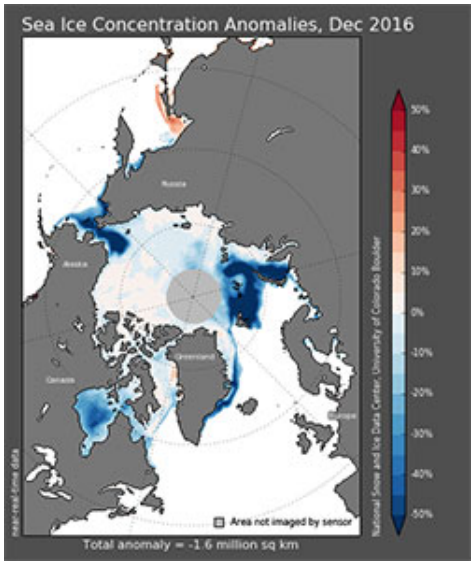


Figure 7a. Monthly Sea Ice Concentration Anomaly Image for the Northern Hemisphere. Note that the SMMR Arctic pole hole, light gray circle in the center of the image, is used for calculating the anomalies.

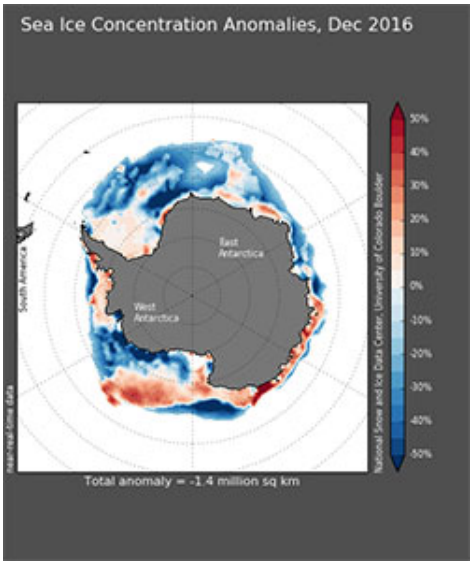


Figure 7b. Monthly Sea Ice Concentration Anomaly Image for the Southern Hemisphere.

3.1.4 Monthly Sea Ice Concentration Trend Images

These images of trends in sea ice concentration, like those in Figures 8a and 8b, show if the trend in sea ice concentration at a particular grid cell location is positive or negative and give some indication of its magnitude. The SMMR Arctic Pole Hole appears on these Arctic images (the large light gray circle seen in Figure 8a), because the trend in concentration is derived over a period that includes SMMR data so the largest hole must be used for the calculations for continuity.

Note: While the images of concentration trends can be interesting, these images should be used with caution for two reasons. First, the accuracy of passive microwave derived sea ice concentration is not good when taken over the relatively small area of a grid cell (Fetterer 2002). Second, what appear to be large trends near the ice edge are often simply artifacts of the movement of the ice edge.

File Naming Convention

`h_mm_trend_[hires]_vX.x.png`

See Table 9 for a description of the naming convention variables.

Processing Steps

1. **Obtain gridded input data.**
   The input data for the sea ice concentration trends are the monthly gridded sea ice concentration data files for a given month, beginning in November 1978. For a description of how these are generated, see the Monthly Sea Ice Concentration Images section of this document.

2. **Derive concentration trends.**
   Least squares regression is used to calculate the trend in ice concentration for that month at each grid cell. Cells that have zero concentration are left out of the time series when calculating trends. The slope of the linear fit gives the trend in concentration at a given grid cell. This number is converted to percent difference in concentration per decade.

3. **Create image from data.**
   Significant trends in concentration are mapped to shades of red (for positive trends) or blue (for negative trends). If the computed trend is not significant to within a 95 percent confidence interval, the grid cell is shown as white.

Access Files

Access the monthly trend images: North and South. Then choose a month from the list of directories labeled by a 2-digit and 3-character month abbreviation and look for files named like those in the convention described above.

Sample Images

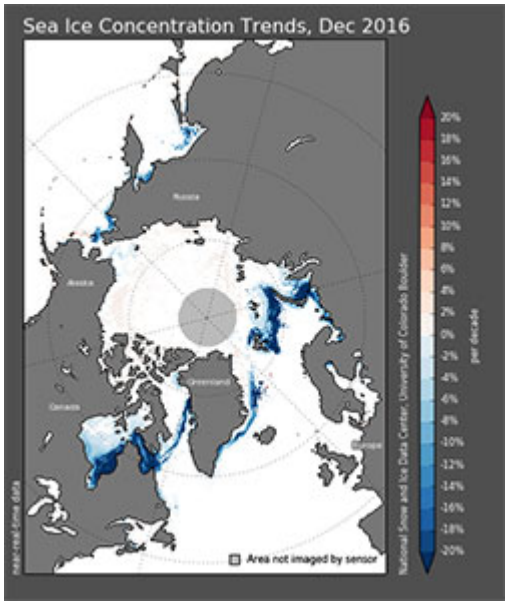


Figure 8a. Monthly Sea Ice Concentration Trends Image for the Northern Hemisphere. Note that the SMMR Arctic pole hole, light gray circle in the center of the image, is used for calculating the trends.

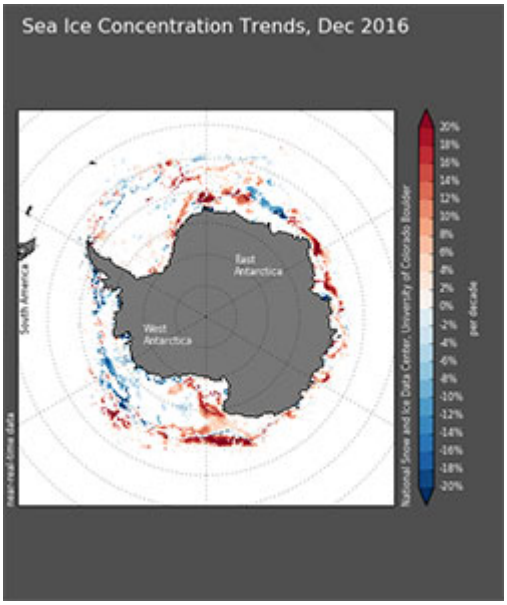


Figure 8b. Monthly Sea Ice Concentration Trends Image for the Southern Hemisphere.

3.1.5 Monthly Sea Ice Extent Anomaly Graphs

These graphs, like those in Figures 9a and 9b, show monthly ice extent anomalies plotted as a time series of percent difference between the extent for the month in question and the mean for that month, where the mean is based on the January 1981 to December 2010 portion of the data set.

File Naming Convention

`h_mm_extent_anomaly_plot_[hires]_vX.x.png`

See Table 9 for a description of the naming convention variables.

Processing Steps

1. **Obtain input data.**
   The input data are those in the extent column of the Monthly Sea Ice Extent and Area Data Files. For a description of how the monthly extent number is computed, see the Compute the sea ice extent step, under the Monthly Sea Ice Extent and Area Data Files section of this document.

2. **Compute ice extent anomaly.**
   To compute the anomaly, the mean extent value for the month in question, using the period 1981 through 2010

for the mean extent, is subtracted from the numbers in the extent column of the Monthly Sea Ice Extent and Area Data Files. The anomaly in ice extent is converted to percent difference by dividing it by the 1981-2010 average and then multiplying by 100.

Example using June 2012:
The June mean extent, based on 1981 to 2010 data, is 11.77 million square km. This is the average of all the values in the extent column of the June Monthly Extent file from the 1981 to 2010 rows. The June 2012 anomaly is the difference between the extent value for June 2012 which is 10.67 million square km and the 1981-2010 June mean extent: 10.67 M sq km - 11.77 M sq km = -1.1 M sq km. The percent difference is then computed: (-0.97 / 11.77) X 100 = -9.35%.

This is continued for every June for the entire time series and then the points are plotted against time to produce the June extent anomaly graph (the black dots signs in Figures 9a and 9b). A similar procedure is applied to all other months to create an anomaly time series graph for each of them.

3. **Compute the trend line.**
   Once the extent anomalies are plotted, the trend (dashed gray line in Figures 9a and 9b) is obtained by applying a simple linear regression (or the slope) to the extent anomaly time series and then multiplying by 10 to give the result in percent per decade. The 95 percent confidence interval for the trend is given at the bottom of the graph. For information on the limits and applicability of linear regression as it applies to the Sea Ice Index, see the Sea Ice Index: Interpretation Resources for Sea Ice Trends and Anomalies document (Fetterer 2002).
4. **Plot data and trend line.**
   The extent anomaly data points are plotted as black dots and the trend line is plotted with a dashed gray line (Figures 9a and 9b).

Access Files

Access the monthly graphs: North and South. Then choose a month from the list of directories labeled by a 2-digit and 3-character month abbreviation and look for files named like those in the convention described above.

Sample Images

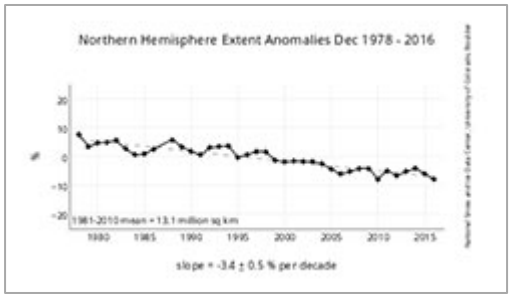


Figure 9a. Monthly Sea Ice Extent Anomalies Graph for the Northern Hemisphere

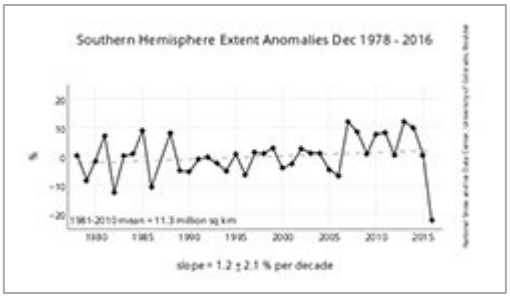


Figure 9b. Monthly Sea Ice Extent Anomalies Graph for the Southern Hemisphere.

3.1.6 Monthly Sea Ice Extent and Area Data Files

These data files are in comma delimited ASCII text format (.csv) and tabulate extent and area, in millions of square kilometers, by year for a given month for the entire time series. There are 12 files, one for each month, for each hemisphere for a total of 24 files. The files contain six columns of data that are described in Table 2. An example of the file is shown in Figure 10.

Table 2. Monthly Data Files Column Description

Column	Description
Year	4-digit year
mo	1- or 2-digit month
data_type	Input data set Goddard: Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-SSMIS Passive Microwave Data NRTSI-G: Near-Real-Time DMSP SSMIS Daily Polar Gridded Sea Ice Concentrations
region	Hemisphere that this data covers N: Northern S: Southern
extent	Sea ice extent in millions of square km
area	Sea ice area in millions of square km

File Naming Convention

`h_mm_extent_vX.x.csv`

See Table 9 for a description of the naming convention variables.

Processing Steps

1. **Obtain the input data.**
   Monthly sea ice extent and area are calculated from daily gridded ice concentration fields. The near-real-time daily data are from the Near-Real-Time DMSP SSMIS Daily Polar Gridded Sea Ice Concentrations (NRTSI product). The final daily data are from the Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-SSMIS Passive Microwave Data (GSFC product).

2. **Compute the gridded average sea ice extent.**
   For each month's average extent, the daily extent for each day of the month is first calculated from the daily gridded input data using the 15 percent concentration cutoff and size of each grid cell[1]. Then, the monthly extent value is obtained by simply averaging the daily extents over the month. Specifically, each cell in the grid counts as either zero sq km or the actual size of the grid depending on whether it passed the 15 percent cutoff or not. Then the values from all the cells are added up to produce a single hemisphere-wide daily extent value in

sq km. Finally, all the daily hemisphere-wide extents for that month are averaged together. We assume that the region not imaged by the sensor at the North Pole, the Arctic Pole Hole, is entirely covered by grid cells showing more than 15 percent concentration for that month, so the region is considered to be ice covered and is included in the extent value.

[1]The size of each grid cell is obtained from static reference files that are noted in the NRTSI product and GSFC product documentation. These files, psn25area_v3.dat and pss25area_v3.dat, are used when calculating the extent. Each grid cell is nominally 625 km^2 (25 km x 25 km), but the area of each cell is slightly different due to the curvature of the Earth and according to the polar stereographic projection that the source data are in. The area is given by multiplying the nominal grid cell size (625 km^2) by the square of the map scale at the center of the grid cell. Grid cell areas range from 382 km^2 to 664 km^2 for the Northern Hemisphere grid domain and 443 km^2 to 664 km^2 for the Southern Hemisphere grid domain. For information on this projection, see NSIDC's Polar Stereographic Projections and Grids Web page.

Note: The extent values are useful in a temporal series, but use caution when citing the numbers apart from the time series or when comparing with values derived from other studies. Ice concentrations are sensitive to the algorithm used, and the resulting numbers for extent depend not only on algorithms but on other processing steps as well. The extent values have uncertain significance when taken individually. For example, the 15 percent concentration cutoff for extent is somewhat arbitrary. Using a 20 percent or 30 percent cutoff gives different numbers, although similar trends, for extent. For examples, see Parkinson et al (1999).

3. **Compute the gridded average sea ice area.**
The monthly average sea ice area calculation is performed exactly the same way as the monthly average extent except that concentration of the ice in each grid cell is taken into account. That is, it is created through simple pixel-by-pixel arithmetic by multiplying the daily concentration by the size of the grid cell[1], for all grid cells which satisfy the 15 percent threshold and then averaging them together for a month. For example, if a grid cell's area is 600 km^2 and its ice concentration is 75 percent, then the ice area for that pixel would be 450 km^2 (600 km^2 x .75).

The area is always less than extent because extent is the entire expanse within the ice edge and includes the Arctic Pole Hole, while area takes ice concentration within that edge into account and excludes the Arctic pole hole. For a complete discussion on the difference between extent and area, see the Frequently Asked Questions on the Arctic Sea Ice Web page: What is the difference between sea ice area and extent?

Note: The *extent* column in the monthly .csv data files includes the area near the pole not imaged by the sensor. It is assumed to be entirely ice covered with at least 15% concentration. However, unlike ice extent, the Arctic values for ice *area* do not include the area near the pole not imaged by the sensor, the Arctic Pole Hole. This area is 1.19 million square kilometers for SMMR (from the beginning of the series through 21 August 1987), 0.31 million square kilometers for SSM/I (22 August 1987 through December 2007), and 0.029 million square kilometers for SSMIS (January 2008 to present). Therefore, there is a discontinuity in the area data values in this file at the August/September 1987 boundary and at the December 2007/January 2008 boundary. Because of this discontinuity, the August 1987 area value has been removed from the time series because of the large difference in the SMMR and SSM/I pole hole.

4. **Append values to appropriate monthly file.**
Each monthly file is updated once a year as that month concludes, unless we receive a new section of the GSFC product final sea ice concentrations, in which case, all files, both image as well as the text data files, are regenerated using the GSFC product final data. **Note:** When insufficient satellite data are available to process the area and extent values, -9999 is substituted for that months area and extent value.

Access Files

Access the monthly data files: North and South.

Sample Data File

year,	mo,	data-type,	region,	extent,	area
1979,	6,	Goddard,	N,	12.53,	9.34
1980,	6,	Goddard,	N,	12.20,	9.00
1981,	6,	Goddard,	N,	12.43,	9.03
1982,	6,	Goddard,	N,	12.48,	9.46
1983,	6,	Goddard,	N,	12.30,	9.27
1984,	6,	Goddard,	N,	12.15,	9.09
1985,	6,	Goddard,	N,	12.22,	8.96
1986,	6,	Goddard,	N,	11.98,	8.99
1987,	6,	Goddard,	N,	12.49,	9.39
1988,	6,	Goddard,	N,	11.94,	9.68
1989,	6,	Goddard,	N,	12.24,	9.95
1990,	6,	Goddard,	N,	11.64,	9.20
1991,	6,	Goddard,	N,	12.11,	9.66
1992,	6,	Goddard,	N,	12.15,	9.95
1993,	6,	Goddard,	N,	11.87,	9.26
1994,	6,	Goddard,	N,	12.02,	9.68
1995,	6,	Goddard,	N,	11.44,	8.94
1996,	6,	Goddard,	N,	12.08,	9.83
1997,	6,	Goddard,	N,	11.74,	9.20
1998,	6,	Goddard,	N,	11.71,	9.18
1999,	6,	Goddard,	N,	11.78,	9.25
2000,	6,	Goddard,	N,	11.67,	9.05

Figure 10. Sample monthly extent data file for June from 1979 to 2000. N_06_extent_v3.0.csv

3.2 Monthly Shapefiles

The shapefiles (. shp) are geospatial vector data for use in geographic information systems (GIS) software. There are two types: extent and median. Extent shapefiles are available for Northern and Southern hemispheres as both polygons and polylines. Median shapefiles are available for Northern and Southern hemispheres as polylines only. See each section below for more information:

- Extent Shapefiles
- Median Shapefiles

3.2.1 Extent Shapefiles

Sea ice extent shapefiles are available for Northern and Southern hemispheres as both polygons and polylines, like those in Figures 11a, b, c, and d, for every month in the times series beginning in November 1978. The polygon files provide a GIS compatible extent shape and the polyline files provide the outline of the extent for a particular month and year.

File Naming Convention

`extent_h_yyyymm_polyline_vX.x.zip`
`extent_h_yyyymm_polygon_vX.x.zip`

Each zipped file contains four files with the same naming convention as above and the following extensions: `.shp`, `.dbf`, `.prj` `.shx`, and `.cpg`.
See Table 9 for a description of the naming convention variables.

Access Files

Access the monthly graphs: North and South. Then choose a month from the list of directories labeled by a 2-digit and 3-character month abbreviation and look for files named like those in the convention described above.

Sample Images

Figure 11a. Northern Hemisphere Sea Ice Extent Polygon Shapefile for April 2010.

Figure 11b. Southern Hemisphere Sea Ice Extent Polygon Shapefile for April 2010

Figure 11c. Northern Hemisphere Sea Ice Extent Polyline Shapefile for April 2010

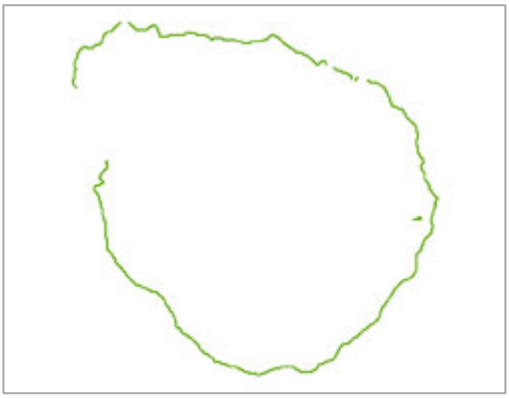


Figure 11d. Southern Hemisphere Sea Ice Extent Polyline Shapefile for April 2010.

3.2.2 Median Shapefiles

The polyline median shapefile, like those in Figures 12a and 12b, provides a GIS compatible ice edge position line that is typical for a month, based on median extent from the period 1981 through 2010. There are a total of 12 files for each hemisphere, one for each month, for a total of 24 files. The polylines are the same as the pink lines overlaid on the extent images. They are described more fully in the Monthly Sea Ice Extent Images section.

File Naming Convention

`median_extent_h_mm_1981-2010_polyline_vX.x.zip`

Each zipped file contains four files with the same naming convention as above and the following extensions: `.shp`, `.dbf`, `.prj` `.shx`, and `.cpg`.
See Table 9 for a description of the naming convention variables.

Access Files

Access the monthly data files: North and South.

Sample Images

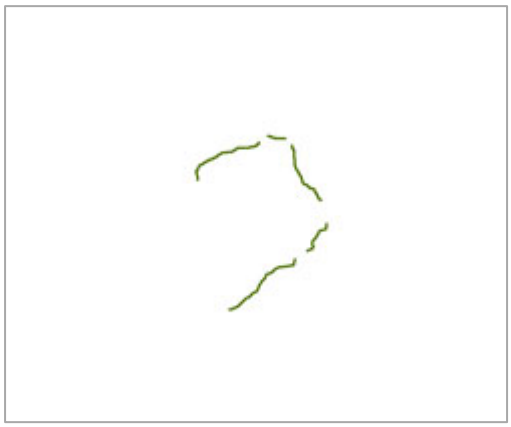


Figure 12a. Northern Hemisphere Median Shapefile for month of April, 1981 - 2010.

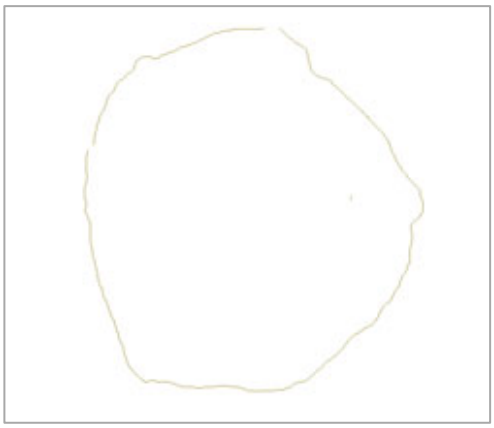


Figure 12b. Southern Hemisphere Median Shapefile for month of April, 1981 – 2010.

3.3 Daily Image and Data Files

These images and data files present ice extent and area on a given day. For near-real-time data, NSIDC runs a daily processing script that obtains the daily gridded NRTSI field and uses it to make the sea ice concentration and extent images and to arrive at that day's ice extent numbers. When the GSFC product becomes available, NSIDC run the processing script again to create the *final* Sea Ice Index product. For a discussion on the difference between extent and area, see the Frequently Asked Questions on the Arctic Sea Ice Web page: What is the difference between sea ice area and extent?

As described in Data Sources, the Sea Ice Index time series is split into two sections: near-real-time and final. Each image contains a label on the left hand side with either the words *near-real-time data* or *final data* to indicate the source of the data either the Near-Real-Time DMSP SSMIS Daily Polar Gridded Sea Ice Concentrations (NRTSI product, NSIDC-0081) or the Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-SSMIS Passive Microwave Data (GSFC product, NSIDC-0051), respectively. The most recent images and data values, for about the last 6 to 18 months, are from the NRTSI product. Older images and data values are from the GSFC product.

All daily images and graphs are provided in PNG (`.png`) format; all data are provided in comma delimited ASCII text files (`.csv`). See each section below for specifics about that file.

- Daily Sea Ice Concentration Images
- Daily Sea Ice Extent Images
- Daily Sea Ice Extent Time Series Graphs
- Daily Sea Ice Extent Data Files
- Daily Climatology Data Files

3.3.1 Daily Sea Ice Concentration Images

The daily concentration images, like those in Figures 13a-d, show the percentage of ice cover for each roughly 25-kilometer-square data cell that is more than 15 percent covered by ice on a given day. The area around the North Pole that is not imaged by the satellite, the Arctic Pole Hole, is excluded from the area because there is no way to know what the concentration is within this area. Due to the nature of near-real-time data, missing pixels of data are often seen. When an image has missing pixels, they are colored yellow and a legend appears on the image alerting users of missing data. Only the near-real-time images will have missing data because the final data go through an interpolation to fill missing pixels. Refer to the Filling Data Gaps section in the GSFC product user guide for more information.

Caution: There is greater uncertainty in daily fields than in the monthly average fields and greater uncertainty in the concentration fields than the extent fields. Areas that appear to have low sea ice concentration often reflect only atmospheric and surface changes, including clouds and water vapor, melt on the ice surface, and changes in the character of the snow and ice surface. Day to day changes seen in the concentration images should be viewed in this light. See the section on Accuracy and Precision of Measurements for more information.

File Naming Convention

`h_yyyymmdd_conc_[blmrbl]_[hires]_vX.x.png`

See Table 9 for a description of the naming convention variables.

Processing Steps

1. **Obtain input data.**
   The input data for the most recent day's concentration image comes from the Near-Real-Time DMSP SSMIS Daily Polar Gridded Sea Ice Concentrations (NRTSI product). Refer to that data set's documentation for specific information on how gridded sea ice concentration is produced.

The input data for the final portion of the Sea Ice Index is the daily portion of the Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-SSMIS Passive Microwave Data (GSFC product). When the GSFC product arrives at NSIDC, the near-real-time daily concentrations images are reprocessed.

2. **Create daily concentration images.**
   Sea Ice Index processing creates the daily concentration fields from the input product as a color-coded image, with a color bar in shades of blue to white to indicate concentration. Concentrations range from 15 percent to 100 percent. Any concentration below 15 percent is set to zero and considered open water due to the uncertainty in passive microwave data at these low concentrations. The color bar is in 10 percent increments. Missing sea ice concentration data appear as yellow dots or areas in the image. The Arctic pole hole is colored dark gray. The median ice edge for that day, shown in orange, is also added to the image.

Access Files

Access the daily concentration images: North and South. Then choose a year directory and then a month from the list of directories labeled by a 2-digit and 3-character month abbreviation and look for files named like those in the convention described above.

Sample Images

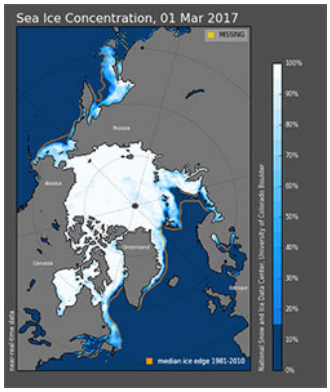


Figure 13a. Daily Sea Ice Concentration Image for the Northern Hemisphere.

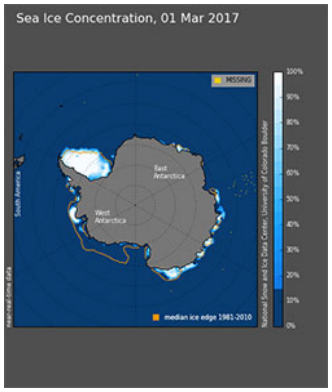


Figure 13b. Daily Sea Ice Concentration Image for the Southern Hemisphere.

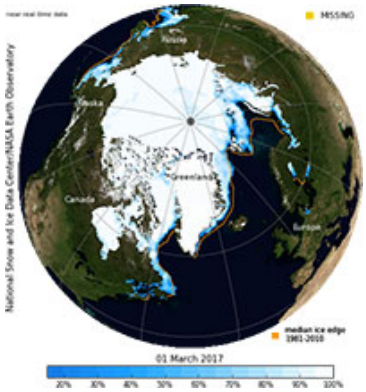


Figure 13c. Blue Marble Version of the Daily Sea Ice Concentration Image for the Northern Hemisphere.

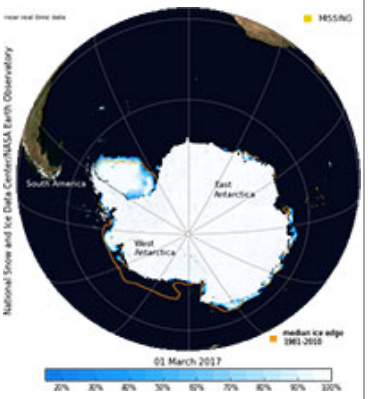


Figure 13d. Blue Marble Version of the Daily Sea Ice Concentration Image for the Southern Hemisphere.

3.3.2 Daily Sea Ice Extent Images

The daily extent images, like those in Figures 14a-d, show the extent of ocean covered by ice at any concentration greater than 15 percent for a given day. The median line, orange in images, shows a typical ice extent for that day based on data from 1981 through 2010. We assume that the area around the North Pole that the satellite does not image is covered by ice at more than 15 percent concentration. Due to the nature of near-real-time data, missing pixels of data are often seen. When an image has missing pixels, they are colored yellow and a legend appears on the image alerting users of missing data. Only the near-real-time images will have missing data because the final data go through an

interpolation to fill missing pixels. Refer to the Filling Data Gaps section in the GSFC product user guide for more information.

Note: Although images may show yellow missing pixels, the Daily Sea Ice Extent Data Files may still show zero in the Missing column because the extent value for that day is filled by interpolation while the images are not.

Caution: The location of the ice edge is not accurate enough for operational purposes.

File Naming Convention

`h_yyyymmdd_extn_[blmrbl]_[hires]_vX.x.png`

See Table 9 for a description of the naming convention variables.

Processing Steps

1. **Obtain input data.**
   Obtain the daily gridded concentration field for the day. See the Daily Sea Ice Concentration Images section of this document for a description of how these gridded concentrations are created.
2. **Create daily extent images.**
   Sea Ice Index processing takes any cell with concentration 15 percent or greater and flags that cell as ice. The extent image is then created with ice colored white, ocean as dark blue, and land as gray. Missing data, whether for a region or an individual cell, appear as yellow dots or areas in the image. The median ice edge for that day, shown in orange, is also added to the image.

Access Files

Access the daily extent images: North and South. Then choose a year directory and then a month from the list of directories labeled by a 2-digit and 3-character month abbreviation and look for files named like those in the convention described above.

Sample Images

Figure 14a. Daily Sea Ice Extent Image for the Northern Hemisphere.

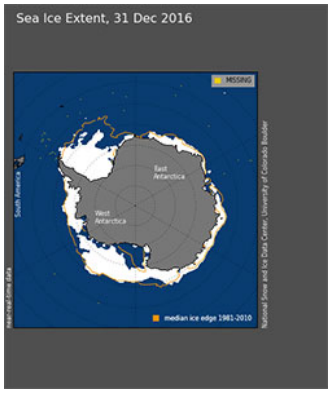


Figure 14b. Daily Sea Ice Extent Image for the Southern Hemisphere.

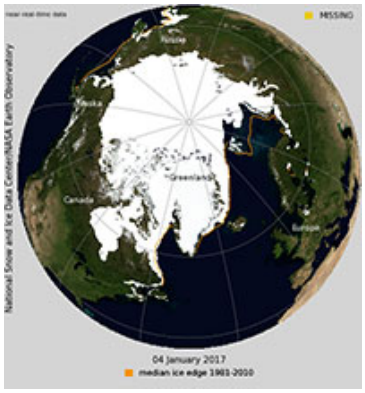


Figure 14c. Blue Marble Daily Sea Ice Extent Image for the Northern Hemisphere.

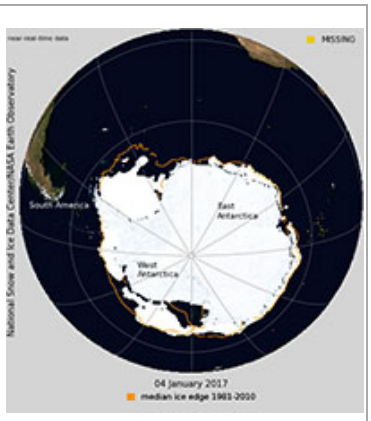


Figure 14d. Blue Marble Daily Sea Ice Extent Image for the Southern Hemisphere.

3.3.3 Daily Sea Ice Extent Time Series Graphs

The daily extent graphs, like those in Figures 15a and 15b, provide a snapshot of changes in Arctic and Antarctic ice extent for the last four months, respectively. The graphs show a time series for both the Northern and Southern hemispheres (solid blue line). Both graphs also include a comparison line for the 1981 to 2010 average (solid gray line) that is plotted for the previous four months as well as the upcoming month. The light gray area around the 1981 to 2010 average line shows the two standard deviation range of the data. This serves as an estimate of the expected range of natural variability.

The graphs include lines for a selected earlier year, for comparison. These are described as follows:

Northern Hemisphere
Along with current extent and the 1981-2010 average extent, the daily extent graph also includes the extent during 2012 (dashed green line). As of January 2017, this was the year with the record low minimum extent. Note that during the transition across the calendar year, data from 2011 or 2013 are included for continuity of the plot with the 2012 record year. This comparison shows the substantial recent change observed in Northern Hemisphere sea ice.

Southern Hemisphere
The daily extent graph for the Southern Hemisphere shows the previous year as a comparison (dashed blue line). During the transition across the calendar, data from the year before or the year after the comparison year are included.

Processing Steps

1. **Obtain input data.**
   The input data for these graphs are the last four months of data from the daily extent data files and the climatology data file for mean extent values over the last four months plus one month into the future. For a description of how the daily extent file is created, see the Daily Sea Ice Extent Data Files section of this document. For a description of the climatology data, see the Daily Climatology Data Files section.

2. **Reduce erroneous artifacts.**
   On daily scales, these extent values can have fairly large variations, both due to real changes in ice extent from growth, melt, or from motion of the ice edge, and due to ephemeral weather and surface effects. To reduce erroneous variations, a 5-day trailing mean is used in the plot. This is calculated by averaging the extent value from a given day with the extent value from the previous four days to produce a 5-day average, so the value plotted for a day is the average of that day and the four previous days.

   Note: With a 5-day trailing average, the average value on the last day will be higher than the true daily value when ice is decreasing (during the melt season) and lower than the true daily value when ice is increasing (during freeze-up). Computing the average may change the value that is plotted, but the value in the data file stays the same. However, this may change slightly if missing data are filled. For more information, see processing Step 2: Compute Extent under the Daily Sea Ice Extent Data Files section. For the 1978 to 1987 SMMR period where extent values are only available every other day, we interpolate between days to create daily time series for the plot.

3. **Plot data.**
   The most recent four months of extent data are plotted in blue. The climatology is plotted in gray with its

standard deviation (the light gray swath around the climatology line). The comparison line is also drawn: dashed green for Northern Hemisphere and dashed blue for Southern Hemisphere.

Access Files

These graphs are not archived, however, the daily extent value data file and daily climatology file used to make them are. To access the most recent daily extent time series graph, see the Sea Ice Index Web site. To plot different years of daily extents, see the Charctic Interactive sea ice graphing tool.

Sample Images

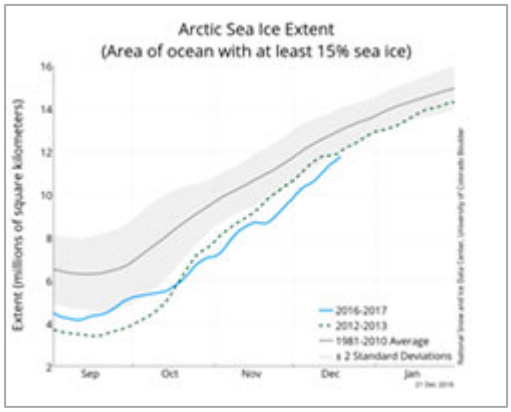


Figure 15a. Daily Sea Ice Extent Time series with standard deviation graph for the Northern Hemisphere.

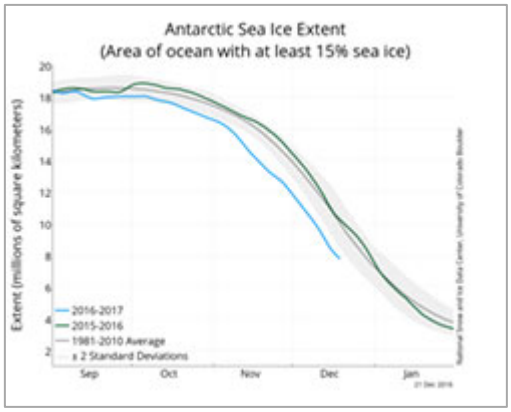


Figure 15b. Daily Sea Ice Extent Time series standard deviation graph for the Southern Hemisphere.

3.3.4 Daily Sea Ice Extent Data Files

These files provide the Arctic- or Antarctic-wide sea ice extent for each day for the entire period of record. There is one daily data file for each hemisphere that provides extent computed the NRTSI product's daily gridded concentration files combined with the extent computed from the GSFC product's daily gridded concentration files. Daily extent from the NRTSI product begins where daily extent from the GSFC product ends. See the Temporal Coverage and Resolution section for the specific dates.

The data files are in comma-delimited ASCII text format (`.csv`). The first two lines of the files are header rows, and they contain six columns of data that are described in Table 3. An example of the data file is shown in Figure 16.

Table 3. Daily Data Files Column Description

Column	Description
Year YYYY	4-digit year
Month MM	1- or 2-digit month
Day DD	1- or 2- digit day of month
Extent	Sea ice extent in millions of square km
Missing	Total of missing data, in millions of square km, in regions that are not masked. Note: These missing values may include regions not covered by sea ice, for example open ocean and land.
Source Data	The FTP address of the input data file used to create the extent data value: nsidc0051_gsfc_nasateam_seaice is in the FTP address: Data from GSFC product. nsidc0081_nrt_nasateam_seaice is in the FTP address: Data from NRTSI product. Generally only the most recent year of data is processed with near-real-time data before being reprocessed into final data. For near-real-time data, this column will often include up to three near-real-time input files due to the interpolation of missing data. See the Processing Steps, below, for details.

File Naming Convention

`h_seaice_extent_daily_vX.x.csv`

See Table 9 for a description of the naming convention variables.

Processing Steps

1. **Obtain input data.**
   The daily data files have extent numbers derived from the daily portion of two input sources: The Near-Real-Time DMSP SSMIS Daily Polar Gridded Sea Ice Concentrations (NRTSI product) and the Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-SSMIS Passive Microwave Data (GSFC product) .

   In both of these products, there are often several scattered grid cells with no data due to the limitations of the sensor. In the GSFC product, these missing regions are filled in by interpolation of values from the day before and the day after during the production of the gridded concentration fields at NASA, before they arrive at NSIDC. Refer to the Filling Data Gaps section in the GSFC product user guide for more information.

   In the NRTSI product, the data arrive at NSIDC with missing data. The Sea Ice Index processing code fills missing

data in a way similar to that used for the GSFC product — by interpolating data from the day before and day after. The exception is at the beginning of the time series, when only the day before is available. In some cases, even after interpolation, some missing grid cells remain. The area of these cells is summed and provided in the column labeled Missing. The area in this column may include ice-free areas, so the missing area cannot simply be added to the extent to obtain corrected extent. Sea ice extent values should be used with caution if there are missing grid cells.

The way missing data are handled in the input data is noted in the Consistency of the Data Record section of this document.

2. **Compute extent.**
The final data have values for ice extent obtained by summing the area covered by all grid cells in the GSFC product that have 15 percent or greater ice concentration. The near-real-time data have values for ice extent obtained by summing the area covered by all grid cells in the NRTSI product that have 15 percent or greater ice concentration, after the Sea Ice Index processing has filled grid cells that are missing data.

The most recent sea ice extent value (last line) in the daily data files may change slightly the next day (day n+1), when both a day before (day n-1) and a day after (day n+1) become available in the NRTSI product gridded concentration time series, allowing interpolation to fill any missing data in day n's gridded concentration field. When missing data cells have been filled, the extent value for day n is recalculated. This may change day n's extent value slightly if the gridded concentration on day n was missing a considerable amount of data. **Note:** Because of this, if you download the daily file one day and then download it again the next day, the last value in the file from the first day you downloaded it (day n), is the second to last value on the second day's download (day n+1), and this value may have changed slightly.

We assume that the area not imaged by the sensor near the North Pole is entirely covered by ice at more than 15 percent concentration, so the Arctic Pole Hole area contributes to the ice extent number.

The area of each grid cell is obtained from static reference files that are noted in the NRTSI product and GSFC product documentation. These files, psn25area_v3.dat and pss25area_v3.dat, are used when calculating the extent. Each grid cell is nominally 625 km^2 (25 km by 25 km), but the area of each cell is slightly different due to the curvature of the Earth and according to the polar stereographic projection that the source data are in. The area is given by multiplying the nominal grid cell size (625 km^2) by the square of the map scale at the center of the grid cell. Grid cell areas range from 382 km^2 to 664 km^2 for the Northern Hemisphere grid domain and 443 km^2 to 664 km^2 for the Southern Hemisphere grid domain. For information on this projection, see NSIDC's Polar Stereographic Projections and Grids Web page.

The extent values are useful in a temporal series, but caution should be used citing the numbers apart from the time series or comparing with values derived from other studies. Ice concentrations are sensitive to the algorithm used, and the resulting numbers for extent depend not only on algorithms but on other processing steps as well. The extent values have uncertain significance when taken individually. For example, the 15 percent concentration cutoff for extent is somewhat arbitrary. Using a 20 percent or 30 percent cutoff gives different numbers, although similar trends, for extent. For examples, see Parkinson et al (1999).

3. **Append values to daily data file.**
The daily data file is updated daily with near-real-time data. When new GSFC data become available, approximately every 6 to 18 months, the daily data file is updated with final data. The final data only have an extent value every other day for the SMMR portion of the record (26 October 1978 through 20 August 1987). The 14 September 1984 ice concentration field contains bad data, so the extent value is in error. The value is

provided for completeness, but should not be used in analysis. At a future date, reprocessing of Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-SSMIS Passive Microwave Data (GSFC product) will correct this date. There are no data from 3 December 1987 to 13 January 1988 due to satellite problems.

Access Files

To access the daily data click on the links below.

- Northern Hemisphere: N_seaice_extent_daily_v3.0.csv
- Southern Hemisphere: S_seaice_extent_daily_v3.0.csv

Sample Data File

```
Year, Month, Day,     Extent,    Missing, Source Data
YYYY,    MM,  DD, 10^6 sq km, 10^6 sq km, Source data product web site: http://nsidc.org/data/nsidc-0051.html
1978,    10,  26,     10.231,      0.000, ftp://sidads.colorado.edu/pub/DATASETS/nsidc0051_gsfc_nasateam_seaice/final-gsfc/north/...
1978,    10,  28,     10.420,      0.000, ftp://sidads.colorado.edu/pub/DATASETS/nsidc0051_gsfc_nasateam_seaice/final-gsfc/north/...
1978,    10,  30,     10.557,      0.000, ftp://sidads.colorado.edu/pub/DATASETS/nsidc0051_gsfc_nasateam_seaice/final-gsfc/north/...
1978,    11,  01,     10.670,      0.000, ftp://sidads.colorado.edu/pub/DATASETS/nsidc0051_gsfc_nasateam_seaice/final-gsfc/north/...
1978,    11,  03,     10.777,      0.000, ftp://sidads.colorado.edu/pub/DATASETS/nsidc0051_gsfc_nasateam_seaice/final-gsfc/north/...
1978,    11,  05,     10.968,      0.000, ftp://sidads.colorado.edu/pub/DATASETS/nsidc0051_gsfc_nasateam_seaice/final-gsfc/north/...
1978,    11,  07,     11.080,      0.000, ftp://sidads.colorado.edu/pub/DATASETS/nsidc0051_gsfc_nasateam_seaice/final-gsfc/north/...
1978,    11,  09,     11.189,      0.000, ftp://sidads.colorado.edu/pub/DATASETS/nsidc0051_gsfc_nasateam_seaice/final-gsfc/north/...
1978,    11,  11,     11.314,      0.000, ftp://sidads.colorado.edu/pub/DATASETS/nsidc0051_gsfc_nasateam_seaice/final-gsfc/north/...
1978,    11,  13,     11.460,      0.000, ftp://sidads.colorado.edu/pub/DATASETS/nsidc0051_gsfc_nasateam_seaice/final-gsfc/north/...
1978,    11,  15,     11.539,      0.000, ftp://sidads.colorado.edu/pub/DATASETS/nsidc0051_gsfc_nasateam_seaice/final-gsfc/north/...
1978,    11,  17,     11.696,      0.000, ftp://sidads.colorado.edu/pub/DATASETS/nsidc0051_gsfc_nasateam_seaice/final-gsfc/north/...
1978,    11,  19,     11.870,      0.000, ftp://sidads.colorado.edu/pub/DATASETS/nsidc0051_gsfc_nasateam_seaice/final-gsfc/north/...
1978,    11,  21,     12.053,      0.000, ftp://sidads.colorado.edu/pub/DATASETS/nsidc0051_gsfc_nasateam_seaice/final-gsfc/north/...
```

Figure 16. First 16 lines of the Northern Daily Sea Ice Extent Data File (N_seaice_extent_daily_v3.0.csv).

3.3.5 Daily Climatology Data Files

These files contain the daily average extent data for 1981 to 2010 and its standard deviation. These are plotted as the solid gray line and the light gray swath, respectively, in the Daily Sea Ice Extent Time Series Graphs. In addition, these files also contain columns for the interdeciles (10th and 90th) and interquartiles (25th, 50th, and 75th). The data files are in comma delimited ASCII text format (`.csv`). The files contain eight columns of data that are described in Table 4. A sample of the data file is shown in Figure 17.

Table 4. Daily Data Files Column Description

Column	Description
DOY	3-digit day of year
Avg Ext	Average sea ice extent in millions of square km from 1981 to 2010.
Std Deviation	Standard deviation of the average extent from 1981 to 2010 in millions of square km.
10th	The 10th percentile of the interdecile range.

25th	The 25th percentile of the interquartile range.
50th	The 50th percentile of the interquartile range.
75th	The 75th percentile of the interquartile range.
90th	The 90th percentile of the interdecile range.

File Naming Convention

`h_seaice_extent_climatology_1981-2010_vX.x.csv`

See Table 9 for a description of the naming convention variables.

Processing Steps

1. **Obtain input data.**
   The input for the climatology files is the final Daily Sea Ice Extent Data File. Values from 1981 through 2010 are used. See the Daily Sea Ice Extent Data file section for information on how this is processed.

2. **Fill missing extent values**
   For years that are missing an extent value on a given date, the value is filled by averaging the value from the day before with the value from the day after. This happens frequently for the data from 1979 to 1987 because the SMMR sensor only collected brightness temperature data every other day. Since sea ice extent values are highly correlated from one day to the next, this is a reasonable thing to do.

   If there are no values on the day before or day after, that day is omitted from the calculation of the average, standard deviation, and percentiles. The climatological extent value for that day has one less data point contributing to it for the 30 years from 1981 through 2010. That is, 29, rather than 30, extent values go into the calculation. This happens for 3 December 1987 to 13 January 1988 when there are about six weeks of no data.

3. **Compute mean, standard deviation, interquartiles, and interdeciles.**
   Each day-of-year's average extent, standard deviation in extent, and interquartiles and interdeciles are calculated from the daily extent values for that day-of-year (DOY) over the year range 1981 through 2010. **Note:** Leap years (there are six from 1981 through 2010) introduce a complication: DOY 60 corresponds to February 29 in a leap year, but to March 1 in other years. DOY 366 is always 366 days from the first of the year, and for most years that corresponds to January 1st of the following year, but for leap years DOY 366 is December 31.

Access Files

To access the climatology data click on the links below.

- Northern Hemisphere: N_seaice_extent_climatology_1981-2010_v3.0.csv
- Southern Hemisphere: S_seaice_extent_climatology_1981-2010_v3.0.csv

Sample Data File

```
std Years = 1981-2010
DOY,   Average Extent,   Std Deviation,      10th,      25th,      50th,      75th,      90th
001,           13.778,           0.407,    13.183,    13.479,    13.823,    14.095,    14.257
002,           13.842,           0.434,    13.201,    13.538,    13.886,    14.164,    14.321
003,           13.891,           0.443,    13.264,    13.502,    13.884,    14.283,    14.369
004,           13.930,           0.443,    13.284,    13.590,    13.925,    14.288,    14.417
005,           13.978,           0.437,    13.349,    13.617,    14.036,    14.304,    14.470
006,           14.028,           0.447,    13.388,    13.645,    14.139,    14.359,    14.512
007,           14.091,           0.440,    13.473,    13.761,    14.188,    14.419,    14.547
008,           14.132,           0.451,    13.454,    13.846,    14.303,    14.434,    14.595
009,           14.170,           0.455,    13.513,    13.797,    14.310,    14.493,    14.640
010,           14.196,           0.461,    13.570,    13.915,    14.240,    14.507,    14.696
```

Figure 17. Sample lines from the Northern Hemisphere Daily Climatology Data File. Shows the two header rows and then the first ten rows of data. N_seaice_extent_climatology_1981-2010_v3.0.csv

3.4 Google Earth Files

These files provide views of the September minimum sea ice extent and March maximum extent on a virtual globe such as Google Earth™. September and March mean monthly extent for each year since 1979 are provided as separate layers.

Processing Steps

1. **Obtain input data.**
   The input for these files are the Monthly Sea Ice Extent Images.
2. **Create Google Earth files.**
   Load each extent image into a `.kml` file and zip the file into a `.kmz` file.

Access Files

To access the Google Earth files, click the following ling: NSIDC_SeaIceExtent.kmz

Sample Image

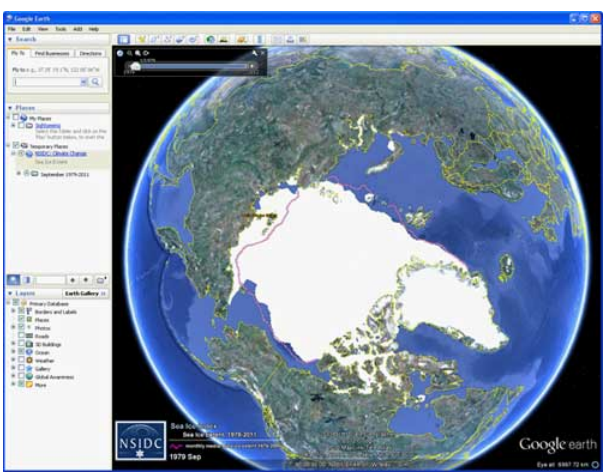


Figure 18. Sea Ice Index in Google Earth

3.5 GeoTIFF Files

GeoTIFF files are available for both concentration and extent data for both hemispheres and both temporal resolutions (daily and monthly). The GeoTIFF images are single band images with an embedded color table to make visualizations of the dataset in GIS programs as easy as possible. See each section below for specifics about those files:

- Daily and Monthly Concentration GeoTIFF Files
- Daily and Monthly Extent GeoTIFF Files

3.5.1 Daily and Monthly Concentration GeoTIFF Files

The daily and monthly concentration GeoTIFF files provide the Sea Ice Index concentration data in a georeferenced format. Table 5 describes the surface classification values and colors in the concentration GeoTIFF files.

Table 5. Concentration Surface Classification Values and Colors

Classification	Value	Color (name/[RGB])
sea ice concentration	0-1000 (divide by 10 to get percent)	Shades of blue starting with dark blue [9, 60, 112], which is considered open ocean (0% ice), through light blue, which is considered varying concentrations of ice, to white [255, 255, 255] which is considered 100% ice. Note: Values from 1-150 (1% to 15% concentration) are statistically irrelevant because data values less than 15% from passive microwave instruments are too uncertain to use, so these should be ignored.
ocean	0	dark blue [9, 60, 112]
pole hole	2510	dark gray [79, 79, 79]
coast line	2530	black [0, 0, 0]
land	2540	gray [119, 119, 119]
missing	2550	yellow [233, 203, 0]

File Naming Convention

Daily: `h_YYYYMMDD_concentration_vX.x.tif`

Monthly: `h_YYYYMM_concentration_vX.x.tif`

See Table 9 for a description of the naming convention variables.

Processing Steps

1. **Obtain gridded input data.**
   Processing begins with ice concentration data in the form of arrays, or gridded fields.

   Daily: The input data for the daily, near-real-time concentration GeoTIFFs comes from the daily Near-Real-Time DMSP SSMIS Daily Polar Gridded Sea Ice Concentrations (NRTSI product). The input data for the final concentration GeoTIFFs comes from the daily Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-SSMIS Passive Microwave Data (GSFC product).

   Monthly: The near-real-time monthly concentration GeoTIFFs are constructed from the *daily* Near-Real-Time DMSP SSMIS Daily Polar Gridded Sea Ice Concentrations (NRTSI product). The final monthly concentration GeoTIFFs are constructed from the *monthly* portion of the Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-SSMIS Passive Microwave Data (GSFC product) because the GSFC product contains a monthly averaged version and the NRTSI product does not.
2. **Derive concentration fields.**
   Daily: Sea Ice Index processing creates the daily concentration fields from the input product mentioned in Step 1. A threshold value of 15 percent is used as a cut off for the lowest ice concentration because data values less than 15 percent from passive microwave instruments are too uncertain to use.

   Monthly: For constructing a month's *near-real-time* mean concentration field, NSIDC uses the *daily* NRTSI product mentioned in Step 1. To do this, the record of *daily* concentration at each grid cell is averaged to produce an *intermediate* Sea Ice Index version of the monthly gridded ice concentrations. This is termed an intermediate product because it is used only for Sea Ice Index processing. Then, a threshold value of 15 percent is used as a cut off for the lowest ice concentration because data values less than 15 percent from passive microwave instruments are too uncertain to use. Therefore, values less than 15 percent are set to be 0 percent ice and the rest of the data ranges from 15 percent to 100 percent concentration. Occasionally, data from one or more days within the month are missing for a given 25 km grid cell. Monthly averages are computed from the daily product data for that cell only if there are at least 20 days of data for that cell. Otherwise, the cell is labeled as missing.

   For constructing a month's *final* mean concentration field, NSIDC uses the *monthly* gridded GSFC product mentioned in step 1. Then, the 15 percent cutoff is applied. Occasionally, values greater than 100 percent occur in the input product; these are set to 100 percent ice in the Sea Ice Index.
3. **Scale data.**
   Before creating the concentration GeoTIFFs, the data are scaled by 10 so that color table entries can be created for each value because color tables must be indexed by an integer value. The original concentration data are fractional, for example 80.3%, therefore you must divide the value in the GeoTIFF by 10 to get the actual percent concentration. Scaling of the concentration data requires that the concentration GeoTIFFs be 16-bit images.
4. **Create GeoTIFFs.**
   GeoTIFF creation is accomplished using Python bindings to the Geospatial Data Abstraction Library (GDAL). For the concentration GeoTIFFs, these are created using unsigned 16 bit values with associated geographic metadata and color table. The concentration GeoTIFFs have embedded colors with ice concentration colored in shades of blue to white, ocean as dark blue, land as gray, coast as black, pole hole as dark gray, and missing data as yellow. See Table 5 for land surface data values and colors.

Access Files

Daily concentration GeoTIFF files: North and South. Then choose a year directory and then a month from the list of directories labeled by a 2-digit and 3-character month abbreviation and look for files named like those in the convention

described above.

Monthly concentration GeoTIFF files: North and South. Then choose a month from the list of directories labeled by a 2-digit and 3-character month abbreviation and look for files named like those in the convention described above.

Sample Images

Figure 19a. Northern Hemisphere Daily Concentration GeoTIFF. Areas in brighter white represent higher ice concentrations and darker shades of blue represent lower concentration. Missing data is plotted as yellow.

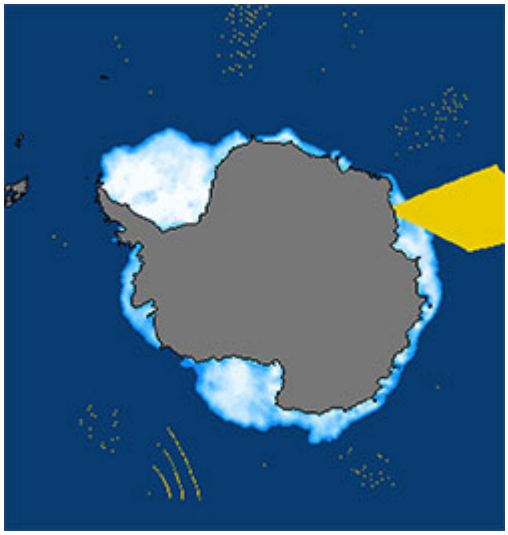


Figure 19b. Southern Hemisphere Daily Concentration GeoTIFF. Areas in brighter white represent higher ice concentrations and darker shades of blue represent lower concentration. Missing data is plotted as yellow.

3.5.2 Daily and Monthly Extent GeoTIFF Files

The daily and monthly extent GeoTIFF files provide the Sea Ice Index extent data in a georeferenced format. Table 6 describes the surface classification values and colors in the extent GeoTIFF files.

Table 6. Extent Surface Classification Values and Colors

Classification	Value	Color (name/[RGB])
sea Ice	1	white [255, 255, 255]
ocean	0	dark blue [9, 60, 112]
coast line	253	black [0, 0, 0]
land	254	gray [119, 119, 119]
missing	255	yellow [233, 203, 0]

File Naming Convention

Daily: `h_YYYYMMDD_extent_vX.x.tif`

Monthly: `h_YYYYMM_extent_vX.x.tif`

See Table 9 for a description of the naming convention variables.

Processing Steps

1. **Obtain input data.**
   Obtain the daily and monthly gridded concentration fields. See the Daily and Monthly Concentration GeoTIFF Files section of this document for a description of how these gridded concentrations are obtained.

2. **Determine extent.**
   Any cell with a concentration of 15 percent or greater is flagged as ice.

3. **Create GeoTIFFs.**
   GeoTIFF creation is accomplished using Python bindings to the Geospatial Data Abstraction Library (GDAL). For the extent GeoTIFFs, these are created using 8 bit values with associated geographic metadata and color table. The extent GeoTIFFs have embedded colors with ice colored white, ocean as dark blue, land as gray, coast as black, and missing data as yellow. See Table 6 for land surface data values and colors.

Access Files

Daily extent GeoTIFF files: North and South. Then choose a year directory and then a month from the list of directories labeled by a 2-digit and 3-character month abbreviation and look for files named like those in the convention described above.

Monthly extent GeoTIFF files: North and South. Then choose a month from the list of directories labeled by a 2-digit and 3-character month abbreviation and look for files named like those in the convention described above.

Sample Images

Figure 20a. Northern Hemisphere Daily Extent GeoTIFF.

Figure 20b. Southern Hemisphere Daily Extent GeoTIFF.

3.6 Ancillary Analysis Spreadsheets

The team of NSIDC scientists who compose articles for the Arctic Sea Ice News and Analysis (ASINA) web site reference data from the Sea Ice Index in the text. Extent and area values, as well as parameters derived from both daily and monthly Sea Ice Index data, are included when composing each post. Rates of change, the rank of daily or monthly extent values in the satellite record, and regional data are among the parameters the ASINA team commonly refers to, and readers often have questions about them. For these reasons, we now include spreadsheets of the parameters in use along with documentation of how they are calculated as an ancillary Sea Ice Index product.

For a complete description of these ancillary spreadsheets, see the Sea Ice Index Analysis Spreadsheets supplementary document.

Access Files

The analysis spreadsheets can be accessed from seaice_analysis directory on FTP.

4 Coverage and Resolution

4.1 Temporal Coverage and Resolution

The Sea Ice Index time series begins in November 1978 and extends through the present. Over this long record, different instruments have been used to capture the data. Table 1, in the Instrument Description section, lists the instruments used by the Sea Ice Index's source data products and gives the temporal coverage of the them. The temporal coverage of the source data products (as of January 2017) is:

- **GSFC Product data:** 26 October 1978 through 31 December 2015. There are no data from 3 December 1987 to 13 January 1988 due to satellite problems.
- **NRTSI Product data:** 01 January 2016 to present.

The temporal resolution of the Sea Ice Index is daily and monthly. Only the monthly data and images are archived. Daily data (extent values) are archived as well. Daily ice extent image files are available for the previous day only and are not archived. Daily ice concentration browse images from the GSFC product and NRTSI product are archived, however. See the NRTSI product site and the GSFC product site and click on the browse directory.

Note: For the SSMR portion of the record, a given polar region was, depending on latitude, only sensed every other day or less. For the SSM/I and later portions of the record, a given polar region was sensed every day.

4.2 Spatial Coverage and Resolution

4.2.1 Coverage, Projection, and Grid Cell Size

Sea Ice Index images and data are based on gridded concentrations that come from a product with a spatial coverage that is north of 30.98° N for the Northern Hemisphere and south of 39.23° S for the Southern Hemisphere. Sea Ice Index images and alphanumeric data are based on gridded concentration data in the NSIDC Polar Stereographic Projection using the Hughes ellipsoid datum and EPSG 3411, for the Arctic, and EPSG 3412, for the Antarctic. For more information, see the Polar Stereographic Projections and Grids Web page.

The GSFC and NRTSI source data products are in a polar stereographic projection and grid that specifies the spatial coverage and grid cell size. The spatial coverage of the Sea Ice Index images is simply a convenient pictorial representation of those Southern and Northern Hemisphere grids.

In the polar stereographic projection, each grid cell is nominally 625 km^2 (25 km by 25 km), but the area actually varies with latitude according to the polar stereographic projection that the source data are in. Grid cell areas range from 382 km^2 to 664 km^2 for the Northern Hemisphere grid domain and 443 km^2 to 664 km^2 for the Southern Hemisphere grid domain. For more information on the GSFC and NRTSI source data projection and grid combination, see NSIDC's Polar Stereographic Projections and Grids Web page and the documentation for the NRTSI and GSFC products.

The area of each grid cell is obtained from static reference files (psn25area_v3.dat and pss25area_v3.dat) that are part of the GSFC and NRTSI data sets. The area of each grid cell is used when summing up ice area from ice concentration for

a grid cell and when summing up the area covered by cells with concentration greater than 15 percent. The summations give hemisphere-wide area and extent values, respectively.

4.2.2 Source Data Resolution

Source data grid cells are nominally 25 km by 25 km, but this is not the same as the resolution of the satellite instrument sensor channels used to create source data ice concentration products. That resolution, or field of view (FOV), is an ellipsoid with a long axis that ranges from about 28 to 69 km, depending on channel frequency and instrument series. Table 7 provides the FOV for the SMMR, SSM/I, and SSMIS channels used by the NASA Team algorithm.

Table 7. FOV for SMMR, SSM/I, and SSMIS by Frequency

Instrument	Frequency (GHz)	FOV (km)
SMMR	18.0	55 x 41 (1)
	37.0	27 x 18 (1)
SSM/I	19.35	69 x 43 (2)
	37.0	37 x 28 (2)
SSMIS	19.35	74 x 45 (3, 4)
	37.0	45 x 28 (3, 4)

1. Gloersen and Barath 1977, 2. Hollinger et al 1990, 3. Northrop Grumman 2002, 4. Kunkee et al. 2008

4.2.3 Arctic Pole Hole

4.2.3.1 Relevance of the Arctic Pole Hole to Ice Extent and Ice Area Values

Due to orbit inclination, the satellite-borne instruments that collect the brightness temperature data that go into creating the Sea Ice Index do not image a circular area over the North and South poles. This area is referred to as the Arctic pole hole. With three different generations of instruments, there are three different Arctic pole hole sizes through the time series. See Table 8.

To account for these holes in the spatial coverage of the data, three Arctic pole hole masks are used, one mask per instrument. They are termed masks because they are overlaid onto the input GSFC and NRTSI ice concentration data by the Sea Ice Index processing code prior to calculating ice extent and area. The holes are significant because, in calculating Northern Hemisphere ice extent, it is assumed that the entire region under the Arctic pole hole is covered by ice at greater than 15 percent concentration. In calculating Northern Hemisphere ice area, however, the region under the Arctic pole hole is not included. Because of this, there is a discontinuity in the time series of Northern Hemisphere

ice area recorded in the Monthly Sea Ice Extent and Area Data Files. This discontinuity, or apparent jump in ice area, occurs in July 1987 when the data source changes from SSMR to SSM/I and in January 2008 when the SSM/I Arctic pole hole mask changes to the SSMIS Arctic pole hole mask. Although SSMIS data begin in 2007, the smaller SSMIS Arctic pole hole mask is not implemented until 2008 to allow for a year of intercomparison between the SSM/I and SSMIS data streams.

Note: The Northern Hemisphere monthly ice concentration anomaly and ice concentration trend images (Figure 7 and Figure 8, respectively) use the larger SMMR hole for the entire time series even when the smaller holes are available. Because the SMMR Arctic pole hole is the largest of the three, it must be used throughout the time series for the continuity needed when calculating trends and anomalies.

Table 8. Arctic Pole Hole Mask Sizes and Dates

Arctic pole hole Mask Name	Arctic pole hole Area (million km^2)	Pole Hole Radius (km)	Latitude	Dates Used
SSMIS Arctic Pole Hole Mask	0.029	94	89.18° N	January 2008 to present
SSM/I Arctic pole hole Mask	0.31	311	87.2° N	July 1987 through December 2007
SMMR Arctic pole hole Mask	1.19	611	84.5° N	November 1978 through June 1987

4.2.3.2 Correction in Application of SMMR Arctic Pole Hole for Daily Data

In March 2015, while editing the data processing code to apply the SSMIS Arctic pole hole mask, it was found that the Sea Ice Index processing code had been applying the SMMR Arctic pole hole mask over the entire Sea Ice Index time series when computing the daily extent numbers instead of using the SSM/I Arctic pole hole mask beginning in July 1987 as the monthly data processing does. Because it is assumed that the entire region under the Arctic pole hole mask is ice-covered and because the SMMR Arctic pole hole mask is relatively large, some sections of open water, regions with less

than 15 percent ice concentration, were being unknowingly included as sea ice in the daily Arctic-wide ice extent number.

At the time of this mask correction, 132 incursions of open water into the SMMR Arctic pole hole mask had taken place in recent years. The first occurred in 1987. However, until 2007, all of these incursions had areas of less than .01 million km^2 which is below the precision of these data. Between 1987 and 2013, the size of the open water in the SMMR Arctic pole hole mask ranged in area from 1800 km^2 to 10,000 km^2. Figure 21 shows the worst-case scenario, 22 September 2009, where approximately 10,000 km^2 crept into the SMMR Arctic pole hole area (red area in Figure 21).

The version 1.2 release of the Sea Ice Index corrects this processing oversight. All concentration data up to the latitude of the appropriate Arctic pole hole are used in the calculation of Arctic-wide extent. As a result of this change, there are slight decreases in the corrected daily extent number for some days in the record. These small changes do not affect the monthly anomalies and trends, however, which are reported to two significant figures.

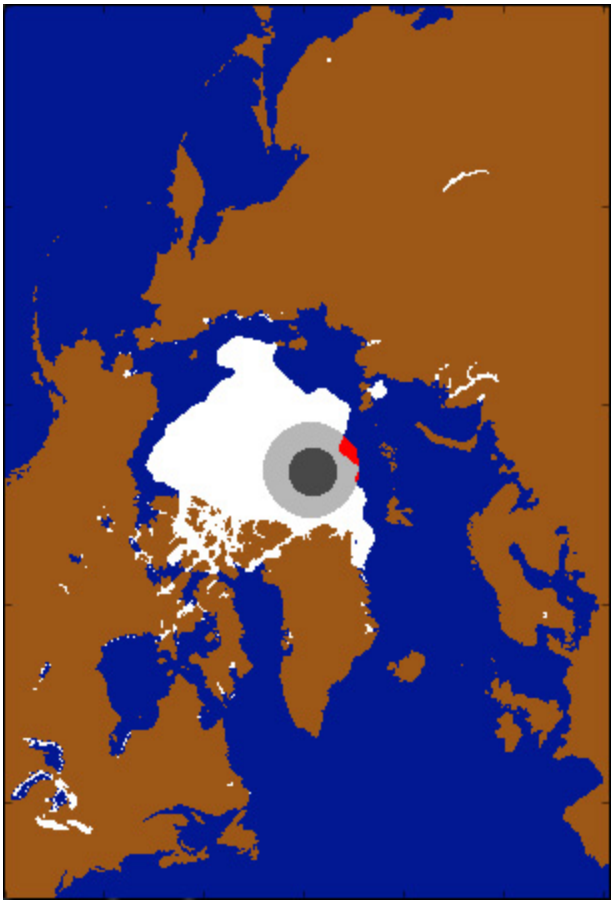


Figure 21. The red area shows where open water has crept into the boundary for the SMMR Arctic pole hole (light gray circle) for 22 September 2009, whereas the SSM/I Arctic pole hole (dark gray) is small enough to not cut off this open water.

5 Additional Information on Accessing and Using Images and Data

5.1 File Naming Convention

The specific naming convention for each file type is given in the Detailed Data Description section. Table 9 describes all of the naming convention variables used.

Table 9. File Naming Convention for Sea Ice Index Files

Variable	Description
h	Hemisphere: N (north) and S (south)
hh	Hemisphere: NH (north) and SH (south)
yyyy	4-digit year
mm	2-digit month
dd	2-digit day of month
anom	Sea ice concentration anomalies
conc	Sea ice concentration
concentration	Sea ice concentration (used in GeoTIFF files)
extn	Sea ice extent (used in image files)
extent	Sea ice extent (used in shapefiles and GeoTIFF files)
plot	Monthly extent anomaly plot.
trend	Sea ice concentration trends
polyline	Type of shapefile. File provides an ice extent contour line.
polygon	Type of shapefile. File provides ice extent.
[blmrbl]	If this is present in the file name, then this file is a Blue Marble image.
[hires]	If this is present in the file name, then this file is a high-resolution image.
_vX.x	Version number (_v3.0: version 3.0)

.cpg	An optional file that can be used to specify the *code page* for identifying the character encoding to be used in a shapefile.
.csv	Comma delimited ASCII text file
.dbf	Attribute format file used by the shapefiles (.shp)
.kml	Google Earth™ file
.kmz	Zipped Google Earth™ file
.png	PNG image file
.prj	Projection file used by the shapefiles (.shp)
.shp	Shapefile. Comes with four associated ancillary files: .dbf, .prj, .shx, and .cpg
.shx	Shape index format file used by the shapefiles (.shp)
.tif	GeoTIFF file
.zip	Zipped data file (data compression format)

5.2 Directory Structure

Daily and monthly images and data files, and monthly shapefiles are available on the FTP site in the `ftp://sidads.colorado.edu/DATASETS/NOAA/G02135` directory. Within the top level directory, `G02135`, there are two subdirectories: `north` and `south`. They are described in detail in Table 10.

Table 10. Description of Sea Ice Index FTP Directory

Directory	Description
north, south, and seaice_analysis	The data are broken up into two regions: `north` and `south`. The north directory contains all of the Arctic data and images and the south directory contains all of the Antarctic data and images. The `seaice_analysis` directory contains seven ancillary sea ice analysis spreadsheets.

north/daily and south/daily	Contains the data and images for the daily product divided into three subdirectories: `data`, `geotiff`, and `images`. The `data` directory contains the daily data files; the `images` directory contains the daily images; the `geotiff` directory contains all of the daily GeoTIFF data files. The `geotiff` and `images` directories are further divided into subdirectories by year and month in the form `YYYY/XX_MMM`, where `YYYY` is the 4-digit year and `XX_MMM` are the 2-digit month and 3-letter month abbreviation.
north/monthly and south/monthly	Contains the data, GeoTIFFs, images, and shapefiles for the monthly product divided into three subdirectories: `data`, `geotiff`, `images`, and `shapefiles`. The `data` directory contains the monthly data files; the `geotiff` directory contains all of the monthly GeoTiff files, the `images` directory contains the monthly images, and the `shapefiles` directory contains the monthly shapefiles. The `geotiff` and `images` directories are further divided into subdirectories by month in the form `XX_MMM`, where `XX_MMM` are the 2-digit month and 3-letter month abbreviation. The `shapefiles` directory is further divided into `shp_extent` and `shp_median` directories which contain the monthly sea ice extent shapefiles and the median extent for the 1981-2010 climatological period, respectively.

5.3 File Size

Refer to Table 11 for a listing of file types and their sizes.

Table 11. File Sizes on the FTP Archive

File Type	Low-res Size	Hi-res Size	Blue Marble Low-res Size	Blue Marble Hi-res Size
Monthly Images	49 KB - 71 KB	188 KB - 241 KB	194 KB - 214 KB	1.4 MB - 1.6 MB
Monthly Plots	14 KB	55 KB	N/A	N/A
Monthly Extent and Area Data Files	~2 KB	N/A	N/A	N/A
Daily Extent Data Files and Daily Climatology Files	Extent File: 2.1 MB Climatology File: 34 KB	N/A	N/A	N/A
Daily Images	46 KB - 54 KB	173 KB - 194 KB	215 KB - 220 KB	~ 1.6 MB

Shapefiles	Extent Shapefiles: 9 KB - 90 KB Median Shapefiles: 4 KB - 11 KB	N/A	N/A	N/A
Daily and Monthly GeoTIFFs	Concentration GeoTIFFs: 651 KB Extent GeoTIFFs: 136 KB	N/A	N/A	N/A

5.4 Data Access and Tools

Obtain the most recent daily and monthly image files from the Sea Ice Index Web site. Archived monthly image files and daily and monthly data files are available via FTP. The Browse Image Spreadsheet Tool (BIST) is a quick and easy way to display selected monthly images in tabular form, in order to show past images side by side, Figures 22a and 22b are examples. There is also a tool for animating Sea Ice Index images. See Table 12 for details.

Table 12. Tools for Viewing Sea Ice Index Images

Tool	Description
Browse Image Spreadsheet Tool (BIST): Extent, Concentration, and Concentration Anomalies	Display archived images of extent, concentration, and concentration anomalies in tabular format, with up to 12 columns (one for each month), and up to as many rows as there are years in the data set. Figure 23a.
Browse Image Spreadsheet Tool (BIST): Extent and Concentration Trends	Display archived images of extent anomaly graphs with trend lines and concentration trend images in tabular format, with 1 or 2 columns (for anomaly graphs, concentration trend images, or both) and up to 12 rows (one for each month). Figure 23b.
Sea Ice Index Animation Tool	Animate extent, concentrations, concentration anomalies, or concentration trend images.

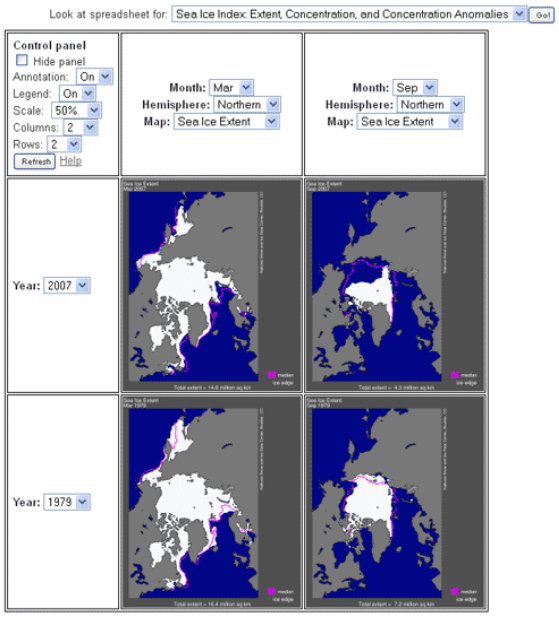


Figure 22a. A screenshot of the Sea Ice Index Extent Anomaly BIST being used to compare March and September ice extent in 1979 and 2007. Click image for a larger version.

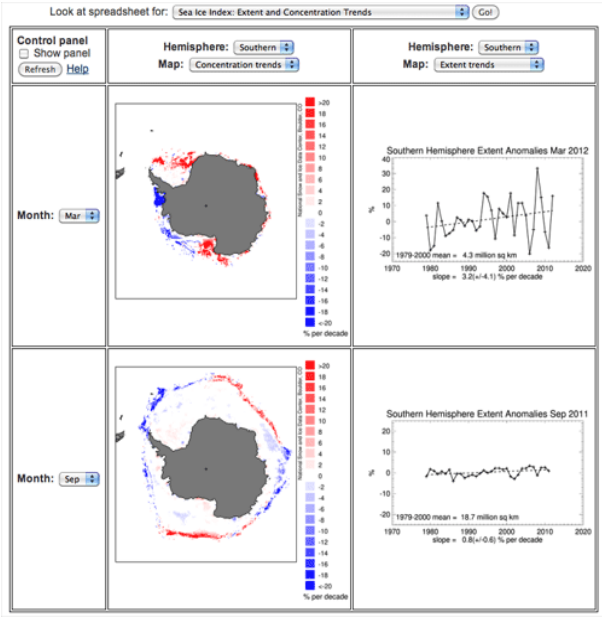


Figure 22b. A screenshot of the Sea Ice Index Concentration Trend BIST being used to compare March and September ice extent in 1979 and 2007. Click image for a larger version.

6 Additional Information on Source Data, Processing, Algorithms, and Accuracy

The most important consideration when making inferences about trends in sea ice over decades is to have a consistently processed, reasonably accurate data record. More accurate records are available for shorter time periods, but these cannot be used to infer long-term trends with as much confidence. Other satellite data or charts from national ice centers are better choices when one wants the best (most accurate and precise) assessment of ice conditions over a shorter time period or in a particular region. The International Ice Chart Working Group has information on national ice centers on their Participating Agencies Web page. Yet, for tracking the response of Arctic and Antarctic sea ice to changing climate, the passive microwave data sets that the Sea Ice Index relies on are a good choice.

Here we briefly discuss information on accuracy and precision and a few of the factors that can result in inconsistencies or inhomogeneities in the record.

- Accuracy and Precision of Measurements
- Land-to-Ocean Spillover
- Valid Ice Masks
- Consistency of the Data Record

6.1 Accuracy and Precision of Measurements

The accuracy of Arctic sea ice concentration at a grid cell in the source data is usually cited as within +/- 5 percent of the actual sea ice concentration in winter, and +/- 15 percent during the summer when melt ponds are present on the sea ice, but some comparisons with operational charts report much larger differences (Agnew 2003, Partington et al 2003). Accuracy tends to be best within the consolidated ice pack where the sea ice is relatively thick (greater than 20 cm) and ice concentration is high. Accuracy decreases as the proportion of thin ice increases (Cavalieri 1995).

Figure 23. Screenshots of the Sea Ice Index daily extent (top) and MASIE daily extent (bottom) from 08 September 2011. The red ellipses show one area, between Banks Island and Victoria Island, where SII and MASIE differ significantly. MASIE is the more accurate product because of the visible band data used as input.

The accuracy of the median sea ice extent edge position for Sea Ice Index products has not been rigorously assessed. It would be difficult to do so, because *ice edge* is not a well-defined parameter. For our purposes, it is where source data grid cells transition from greater than 15 percent to less than 15 percent concentration. Operational services usually speak of a marginal ice zone of varying width over which concentration transitions from more than 90 percent to 0 percent. Spot checks of the sea ice edge position using a 15 percent concentration cutoff against NIC ice charts show that when there is a broad, diffuse ice edge, the NRTSI and GSFC products sometimes do not detect sea ice where the concentration can be as high as 60 percent (Fetterer 2003 poster). When the sea ice edge is more compact, the 15 percent concentration cutoff reflects its location fairly well (Fetterer 2002).

Defining the ice edge in SSM/I data using the 15 percent concentration contour has been common practice since the publication, in 1991, of a study that compared SSM/I ice concentration data from the NASA Team algorithm with coincident data from higher resolution airborne imagery. That study used remote sensing data acquired in March 1988 and found that aircraft-determined ice-edge positions matched the SSM/I 15 percent ice concentration contour (Cavalieri et al. 1991).

Ice concentration from low-resolution passive microwave data is not highly accurate; and for this reason, it is best not to use Sea Ice Index ice concentration images alone, out of temporal context, especially those from a single day. Ice extent images are more reliable, because the difference in emissivity between open water and sea ice, even at low concentrations, is great (Comiso and Kwok 1996). Still, the instrument's low resolution (see Table 7. FOV for SMMR, SSM/I, and SSMIS by Frequency) means that the ice edge, whether it is a compact or diffuse marginal ice zone, will not be represented well. For example, the daily 25 km SII extent product for 08 September 2011 is shown in Figure 23 along with the 4 km Multisensor Analyzed Sea Ice Extent (MASIE) product from the same day. MASIE resolves the ice edge with greater precision and accuracy, but it is not a long and consistently processed record. The Sea Ice Index daily product does a reasonable job, but it is evident why we place higher confidence in monthly than in daily products. Many errors due to missing data and transient weather effects are averaged out when we average daily data over a month.

For addition information on the accuracy and precision of concentration and extent, see the references under the Validation and Comparison of Passive Microwave Algorithms for Sea Ice section within the References and Related Publications of the GSFC product documentation, as well as the informal guide Sea Ice Index: Interpretation Resources for Sea Ice Trends and Anomalies. NSIDC Informal Technical Report (Fetterer 2002).

6.2 Land-to-Ocean Spillover

Ice can be falsely detected along coasts due to contamination of ocean pixels by the passive microwave emission of land. While the nominal grid cell size of the gridded products is 25 km x 25 km, the -3dB footprint of the 19.35 GHz SSM/I and SSMIS passive microwave channel is 72 km x 44 km (Kunkee et al 2008). Both of the input data sets, NTRSI and GSFC, already have land-to-ocean spillover correction applied to them before they are put through SII processing; so no other land-to-ocean spillover correction is applied to the data during SII processing.

To remove spurious Northern Hemisphere coastal ice, both the NRTSI product and the GSFC product processing uses the land spillover correction that is described in NASA Technical Memorandum 104647 (Cavalieri et al, 1997) and in the Sea Ice Concentrations from Nimbus-7 SSMR and DMSP SSM/I Passive Microwave Data guide document. The rationale behind this land spillover approach is that ice will have retreated from most coasts in late summer, so that coastal ice observed at this time by passive microwave instruments is probably a false detection. To reduce the chance of removing ice where it really does exist, the method searches for and requires the presence of open water in the vicinity of the grid cell to be corrected. The method uses the monthly data from 1992 as a basis for correcting SSM/I data and monthly data from 1984 for correcting the SMMR data. It is not completely effective, as Figure 21 illustrates. The ice between Banks Island and Victoria Island (red circled area in the images) is not shown in the MASIE product and is probably the result of land spillover.

6.3 Valid Ice Masks

Weather effects can cause the passive microwave signature of seawater to appear like that of ice (Cavalieri 1995). Atmospheric water vapor or wind roughening of the ocean surface are often the reasons behind false ice detection. Most of these false ice signatures are removed with a standard brightness temperature filter, but some are too close to those of real ice, so an additional valid ice mask is needed. Sea surface temperature fields that show where water is usually too warm for ice, maximum ice extent fields that show where ice has never been before (in the satellite record), or sea ice climatologies can be used to mask out spurious ice resulting from residual weather effects.

Both of the input data sets, NTRSI and GSFC, already have valid ice masks applied to them before they are put through SII processing. However, the SII processing adds an additional valid ice mask to the data processing.

In the processing of the NRTSI product done by NSIDC, valid ice masks based on monthly climatological sea ice charts from NIC are applied to remove spurious ice resulting from residual weather effects in the Arctic. For the southern hemisphere, the GSFC masks based on SST are used. No extra manual removal of false ice is done. For more information, see the Derivation Techniques and Algorithms section of the NRTSI product user guide.

In the processing of the GSFC product done by GSFC, a mask based on monthly climatological sea surface temperature (SST) is used to remove spurious ice resulting from residual weather effects from daily concentration fields for both hemispheres. Some subjective, manual false ice removal is done at GSFC as well. For more information, see the Land Spillover and Residual Weather-Related Effects section of the GSFC product user guide.

To make the two input data sources more consistent, Sea Ice Index processing applies valid ice masks in an additional step described below. The mask set used depends on the hemisphere.

6.3.1 Northern Hemisphere Valid Ice Masks

Spurious ice, from residual weather effects, are removed for the Northern Hemisphere by applying Polar Stereographic Valid Ice Masks Derived from National Ice Center Monthly Sea Ice Climatologies. There are 12 NIC valid ice masks, one for each month. Prior to January 2015, processing used a passive microwave-based maximum ice extent climatology for masks. The main reason for the replacement is that these NIC valid ice masks are less likely to cut off real ice since the charts they are based on are created by sea-ice analysts. The analysts draw an edge beyond which they are confident ice is not present; they make this determination using multiple data sources. This means that the NIC valid ice masks are inherently more conservative than passive microwave data, and they extend back to 1972 providing a longer base record.

Another reason for the change to the new NIC valid ice masks is that the old maximum extent masks would sometimes remove or add ice in months when ice is changing rapidly such as in May and June. This required NSIDC scientists to scrutinize the old masks during these times to make manual adjustments to them so that ice extent was not erroneously added or cut off. An example is the Bering Sea where ice has become more extensive; the old masks risked cutting off real ice, thus the need for manual QC. However, the NIC valid ice masks accommodates the higher ice extent in the Bering, thus eliminating the need for manual QC of the masks. In addition, the NIC charts that the NIC valid ice masks are

based on are a data set distributed at NSIDC; so there is a very clear and documented provenance. Also, the masks have the additional benefit of removing some of the false ice detections that can occur along coastlines.

6.3.2 Southern Hemisphere Valid Ice Masks

For the Southern Hemisphere, masks based on monthly climatological SST from AMSR-E are used to remove spurious ice resulting from residual weather effects from daily concentration fields. This approximates the same mask that GSFC uses for their Antarctic processing. For more information, see the Land Spillover and Residual Weather-Related Effects in the Processing Steps section of the GSFC product user guide. No subjective, manual false ice removal is done.

6.4 Consistency of the Data Record

Inconsistencies or inhomogeneity in the GSFC product data record arise from problems encountered when deriving sea ice concentrations from brightness temperatures measured by sensors with slightly different orbital characteristics, frequencies, and calibrations. The techniques employed to solve these problems, or at least reduce their impacts, are covered in the GSFC product documentation.

The much shorter NRTSI product data record is the result of processing steps designed to mimic GSFC product processing to the greatest degree possible.

The Sea Ice Index data record extends the GSFC product record with the NRTSI product record. Prior to 2004, K. Knowles evaluated consistency between the NRTSI and GSFC products for the year 2002 using brightness temperature data from NSIDC/RSS and near-real-time brightness temperature data from NASA Marshall Space Flight Center (MSFC) as input and then differencing monthly gridded concentration derived from NRTSI daily data with monthly gridded concentration derived from GSFC daily data. We found that the brightness temperature source made little difference in overall extent and area. The differences in the NRTSI- and GSFC-derived monthly area and extent values for the year 2002 were at most 1.6 percent (this was the area difference for June 2002) with most differences much lower or negligible.

This early work showed that joining the GSFC and NRSTI products to create Sea Ice Index products was reasonable: ice extent and area data are processed in a consistent way. Since then, the NRTSI brightness temperature source has changed to the NOAA CLASS, and more recent comparisons by M. Savoie have shown that changes in data source, from the NRTSI product to the GSFC product, can result in slight changes in the Sea Ice Index monthly extent and area values. The changes are generally less than 20,000 km^2 which is equivalent to about 30 to 40 grid cells in area, or much less than 1.0 percent. Whenever new GSFC data is released, the Sea Ice Index reprocesses any data using the NRTSI product for that time period so that only the most recent three to six months of data use the less quality checked NRTSI product.

6.4.1 Algorithm Tie Points

The input NRTSI and GSFC sea ice data products are created using the NASA Team Algorithm (Cavalieri et al. 1997) which converts brightness temperatures to gridded ice concentration estimates. Because each sensor and spacecraft orbit is slightly different, algorithm parameters called tie points sometimes need adjustments so that the time series is consistent. Inconsistencies would be marked by sudden false jumps or drops in derived ice extent at the point when the

algorithm started using data from the new instrument. These tie-point adjustments are derived from regressions of brightness temperatures during satellite overlap periods.

For the GSFC portion of the time series, these tie-points were originally derived for the SMMR sensor (Cavalieri et al. 1984) and were adjusted for subsequent sensors via intercalibration of the concentration/extent fields during sensor overlap periods to ensure consistency through the time series (Cavalieri et al. 1999). The tie-point adjustment procedure and tie-point values for all sensors through F-13 SSM/I are provided in Cavalieri et al. (1999). For the GSFC data, the tie-points for F-17 are described in Cavalieri et al. (2011); for the NRSTI data, the F17 tie-points are described in Meier et al. (2011). For more information, see the NASA Team Sea Ice Algorithm document on the NSIDC Web site.

7 References and Related Publications

7.1 Sea Ice Index References

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Windnagel. A. 2013. Baseline Period Change. NSIDC Web Site. https://nsidc.org/data/seaice_index/baseline-change.html.

Note: In 2013, The base period used for the sea ice index changed from 1979 to 2000, a 22-year period, to a 30-year base period of 1981 to 2010. Extending the baseline to a 30-year period kept the Sea Ice Index in line with other products that show anomalies compared with a climatological norm. However, because sea ice extents generally trend more sharply down from the late 1990s on, extending the baseline to include this period changes the information the Sea Ice Index conveys. The Baseline Period Change article describes and illustrates how the information conveyed by the Sea Ice Index changed.

To help users interpret the images and figures within the Sea Ice Index correctly, the Sea Ice Index: Interpretation Resources for Sea Ice Trends and Anomalies document (Fetterer 2002) discusses the variability of sea ice, the applicability of statistical methods for trend detection, and the validity of passive microwave images of sea ice.

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7.3 Related Data Collections

- Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-SSMIS Passive Microwave Data (GSFC product)
- Near-Real-Time DMSP SSMIS Daily Polar Gridded Sea Ice Concentrations (NRTSI product)
- MASIE (Multisensor Analyzed Sea Ice Extent) daily Arctic-wide ice extent at 4km resolution
- DMSP SSM/I-SSMIS Daily Polar Gridded Brightness Temperatures (NSIDC-0001)
- Near-Real-Time DMSP SSMIS Daily Polar Gridded Brightness Temperatures (NSIDC-0080)
- Arctic Sea Ice News and Analysis (ASINA)
- Sea Ice Index on Virtual Globes
- Sea Ice Trends and Climatologies from SMMR and SSM/I-SSMIS
- All About Sea Ice
- Frequently Asked Questions on Arctic Sea Ice
- Greenland Icesheet Today

7.4 Other Related Data Sets

- Arctic Sea Ice Volume Anomaly, version 2: Sea ice volume data from the Polar Science Center at the Applied Physics Lab at the University of Washington.
- Historical Sea Ice Atlas

7.5 Education Resources

- Sea Ice Index on Virtual Globes: View September minimum extents and March maximum extents in Google Earth™. To access these files, see the *September Sea Ice Extent* and *Sea Ice: Minimum and Maximum Extents* sections on the View NSIDC Data on Virtual Globes: Google Earth Web page. To download a free version of Google Earth, visit the Google Earth Web site.
- Exploring the Cryosphere Using Data from the National Snow and Ice Data Center: Created by the Science Education Resource Center (SERC) through the National Science Digital Library's (NSDL) Using Data in the Classroom program, this K-12 classroom activity uses the Sea Ice Index to teach skills in cryospheric studies and climate change.

8 Contacts, Product History, and Acknowledgments

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8.3 Product History

The Sea Ice Index originated with ideas discussed between Florence Fetterer, NSIDC's NOAA liaison, and Ken Knowles, senior software developer (at NSIDC 1990-2006). The Index was envisioned as a Web site that would meet a need for readily accessible, easy-to-use information on sea ice trends and anomalies, with products that would assist in monitoring and diagnosing the ice extent minima that were gaining increasing attention in the research community in the late 1990s. Ice conditions, trends, and anomalies presented graphically would give at-a-glance answers to general questions such as "Is the ice extent in the Chukchi about where it usually is this time of year?" and "Was there less ice in the Beaufort Sea last spring than is typical?". The Index was and still is intended for both researchers and the scientifically inclined general public.

The Index was developed in 1999 with financial support from the NOAA National Environmental Satellite, Data, and Information Service (NESDIS) and in cooperation with the NOAA National Geophysical Data Center (NGDC). This first version of the Sea Ice Index, published online in 2002, did not include SMMR but started with SSM/I in 1987. For this reason, it was a short time series; and ice extent trends derived from it were often statistically insignificant. In 2000, funding from the NOAA Oceanic and Atmospheric Research (OAR) Arctic program allowed us to do the work necessary to make the SMMR record of ice concentration homogeneous with that of SSM/I. This was a contribution to the Study of Environmental Arctic Change (SEARCH) research project. The new Sea Ice Index, published online in 2004, is a record that begins in 1978.

Originally the Index was not intended to be a data set on its own but to be an information product that simply repackaged existing NSIDC passive microwave sea ice data and presented them graphically as an ongoing series. However, additional processing was necessary to build a consistent, homogeneous ice concentration time series from

SMMR and SSM/I data and to append the NRSTI product to the GSFC product. This led to the decision to make the Index a more traditional NSIDC data set, with standard NSIDC documentation, in 2008.

Major steps in its evolution follow, starting with the most recent changes.

8.3.1 2017

8.3.1.1 October 2017: Sea Ice Index Updated to Version 3.0

The Sea Ice Index has been updated to Version 3 (V3). The key change in this version is an update to the method used to calculate monthly average sea ice extent and area data values that fixes an incongruity between daily and monthly-average Sea Ice Index data. The update was driven by a reassessment of the monthly averaging method, as rapid changes in sea ice over the course of a month have been shown to impact extent values generated by Version 2 (V2). The V3 monthly-average methodology is based on the simple average of hemisphere-wide daily extent values, while the V2 methodology was based on the gridded monthly-average concentration. Now, if one were to average the Sea Ice Index daily data values, the results would match the monthly average Sea Ice Index data values. For complete details on this update, see NSIDC Special Report #19: Sea Ice Index Version 3 Analysis.

May 2017: Addition of Median Extent Line to Concentration Images

To further the understanding of sea ice from the Sea Ice Index, we have added the median sea ice extent line to the concentration images. Previously, this was just shown on the extent images.

April 2017: Release of GeoTIFF format

The Sea Ice Index v2.1 is now available in GeoTIFF format to help facilitate the use of Sea Ice Index in GIS software applications.

January 2017: Sea Ice Index Updated to Version 2.1

The Sea Ice Index has been updated to Version 2.1. The motivation for the update to Version 2.1 was to port the Sea Ice Index IDL code to Python. Prior to V2.1, the Sea Ice Index was processed with code written mainly in IDL with some Perl, Ruby, and C. In an effort to streamline the processing, all of the code has been ported to Python. During this porting, the images and graphs were given an updated look for ease in reading the images and some minor adjustments were made to some computations. However, these changes did not alter any daily data values and only altered five percent of the monthly data values in the second decimal place. These adjustments and updates are explained in Table 13.

NSIDC has chosen to move to Python for a number of reasons. First, Python has excellent community supported libraries for geoscience and time series processing. Second, Python is open source; so code can be shared easily with others. In contrast, IDL is a closed source proprietary language that is expensive for non-university users. The table below describes the Sea Ice Index Version 2.1 updates processed with the Python code.

Table 13. Version 2.1 Updates

Update	Description
New color scheme and updates for the daily and monthly images and graphs	All daily and monthly extent and concentration images now have a new ocean color, latitude and longitude grid lines, and place names for ease in interpreting the polar orientation of the images. The color bar for the legend on the concentration images was updated to reflect the new ocean color. Additionally, the segments on the color bar were updated to accurately depict that Sea Ice Index concentrations begin at 15% due to the accuracy of passive microwave instruments. When there is missing data, they are now displayed in yellow to make it more distinct from the land on the images. In addition, a legend has been added to the images noting that yellow means missing data. Prior to V2.1, missing data were displayed in gray and no legend was present. Monthly anomaly and trend images also now have the latitude and longitude grid lines and place names on the images as well as a new color bar.
New FTP Directory Structure	Sea Ice Index data are now organized by hemisphere at the top level, then parsed by temporal resolution, daily or monthly, and organized further by file type: tabulated data, browse images, or shapefiles. See the Directory Structure structure section for full details.
Daily images and blue marble images now archived on FTP	Due to the demand for the regular daily images and the blue marble versions of the images, NSIDC is making those available in the Sea Ice Index FTP archive in both low resolution and a high resolution versions.
Final monthly data and images now computed with monthly NSIDC-0051 data	To create final monthly sea ice extent and area data, Sea Ice Index V2.1 uses the monthly averaged sea ice concentration data files from the input data source, Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-SSMIS Passive Microwave Data (NSIDC-0051). Previous to this software update, final monthly sea ice index data were computed by averaging the daily sea ice concentration data from the input data set over a month to create a mean monthly concentration. This change was made because the monthly averages in NSIDC-0051 are considered highest quality because they are processed and manually quality checked by GSFC. In addition, this change reduces the computational load on Sea Ice Index processing and decreases the chance of error in the monthly data from re-computing it from daily data. For the Arctic, only 23 of 453 monthly extent and area values changed; and for the Antarctic, 26 of 453 monthly values changed. Of these changes, all except one had an absolute difference of .01 million sq. km. The area for August 1987 Arctic data was reduced by .85 million sq. km due to a change in the Arctic pole hole. Previously, for August 1987, the smaller SSM/I Arctic pole hole was used to calculate area. However, the input NSIDC-0051 monthly data uses the larger SMMR Arctic pole hole. When area is computed for Sea Ice Index, the area under the Arctic pole hole is left out, thus, changing to a larger Arctic pole hole for August 1987 means that the area is lowered by 0.85 million sq. km. This does not change any trends or anomalies in the data set.

Updates to rounding errors in extent and area computations and anomaly computations	A small rounding error was found in the IDL code in the calculation of the V2.0 monthly extent and area data that has been corrected in the V2.1 calculation with the Python code. This error only changed five extent values by .01 million sq. km out of 906 northern and southern data values and only changed three area values out of 906. It was also found that the V2.0 Sea Ice Index, created with the IDL processing code, was introducing rounding errors into the monthly anomaly computation when values are stored as bytes. For example, when a double is stored as a byte in IDL, the data is truncated rather than rounded; so, when IDL sees a values like 14.9999999, it truncates it to 14 instead of rounding to 15. The new Python processing code for V2.1 does not have this issue and rounds instead of truncating. However, fixing this truncation issue changed approximately 13 percent of the total anomaly values displayed on the monthly anomaly images. The maximum difference is +0.1 million sq. km which occurred for 65 values out of 453 in the Northern Hemisphere and 55 out of 453 in the Southern Hemisphere. In addition, 2 of 24 anomaly slopes on the monthly graphs changed due to similar rounding errors in IDL, that are now fixed in the Python version, the anomaly slopes for October and December for the Northern Hemisphere changed by -0.1 and +0.1, respectively.
Change to the way monthly shapefiles are created	V2.1 shapefiles are created with code from trusted Python libraries. Previously, in Versions 2.0 and earlier, the shapefiles were created in IDL with a custom contouring algorithm. Although the differences between the V2.0 and V2.1 shapefiles are minimal, the choice was made to use Python libraries because they are open source and community supported and are backed by the industry standard GDAL library. In addition, a `.cpg` file has been added to the zipped shapefiles which is an optional file that provides the *code page* for identifying the character encoding to be used.
New file name for daily data files and new format for monthly data files	The near-real-time and final daily data files have been merged into one file: `H_seaice_extent_daily_v2.csv`. The monthly data files are now in comma separated files with the following files names: `H_MM_extent_v2.csv` Where H is hemisphere and MM is 2-digit month.
NRT data fills in missing data with final data	In V2.1, if there is missing data in the NRT data at the boundary between where final data ends and NRT data begins, the missing NRT data are interpolated with the day before, which is final data, and the day after, which is NRT data. Previously, final data and NRT data were kept separate; so that when missing NRT data occurred at the boundary, it was just considered missing. For example, when V2.1 was released, final data went to 31 December 2015 and NRT data started on 01 January 2016. The Antarctic NRT data for 01 January 2016 has missing grid cells. The new method interpolates 01 January 2016 with 31 December 2015 final data and 02 January 2016 NRT data, so all of the missing values are filled in. Note, in this example, sea ice extent values actually did not change because none of the missing grid cells were over sea ice.

New computation for Climatology Averages and Standard Deviations	In V2.1, when a day of missing data occurs during the computation of the 1981-2010 climatological average and standard deviation, that day is filled in by averaging the values from the surrounding days, that is, one day before and one day after the missing date. Gaps larger than one day are not filled in. Previously, in Versions 2.0 and earlier, when computing the climatology for missing extent values on a given date, the value was filled in by the value from the day after, if it was available, or if not, by the value from the day before. This can produce a bias in the data during months when the sea ice is melting or freezing rapidly. This new method of averaging alleviates this bias. Although most climatology and standard deviation values did change in the third decimal place and some changed in the second decimal place because of this update, this did not alter any conclusions about the climatological change in sea ice. When V2.0 averages and V2.1 averages are plotted together, there is no visual difference in the values.
Daily climatology data files have a new name and now have columns for deciles and quartiles	The daily climatology file, N_seaice_extent_climatology_1981-2010_v2.csv, now contains the interdeciles (10th and 90th percentiles) and the interquartiles (25th, 50th, and 75th percentiles) along with the usual standard deviation.

8.3.2 2016

July 2016: Sea Ice Index Updated to Version 2

The Sea Ice Index has been updated to Version 2. Changes include using the most recently available version of the GSFC input sea ice concentration data and adjusting three procedures in the Sea Ice Index processing routine. These four updates affected different sections of the Sea Ice Index time series. All of them affected the *final monthly* data and two of them affected the *final daily* data. Additionally, two of the updates affected the *near-real-time monthly* data and one of them affected the *near-real-time daily* data. These updates are briefly described in Table 14 and their effects are fully described in NSIDC Special Report 18: Sea Ice Index Version 2 Analysis (Windnagel, Savoie, and Meier 2016).

Table 14. Sea Ice Index Version 2 Updates

Updates and Corrections	Description	Temporal Coverage/ Resolutions Affected
New version of GSFC input data	Sea Ice Index Version 2 uses V1.1 of the Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-SSMIS Passive Microwave Data (GSFC product) as the input data source for the *final* portion of the Sea Ice Index record. Version 1.1 of the GSFC product has these changes: • Additional manual quality control procedures applied to further remove spurious ice. • Changes in satellite transition dates. • Later end date of 31 December 2015, extending the final portion of the Sea Ice Index Record. The NRT portion now begins on 01 January 2016. See more about GSFC V1.1 in the Version History section of the V1.1 document.	Final Monthly Data Final Daily Data
Redundant 15% concentration threshold	For the monthly Sea Ice Index data, a grid cell is considered ice if the concentration is 15% or greater. Thus, the ice edge is defined by the 15% concentration contour. This convention was established early on by those who developed the NASA Team algorithm for passive microwave data (Cavalieri et al. 1991). It was found that ice concentration values less than 15% have greater uncertainty and may reflect weather effects or other factors. Also, because of the low spatial resolution of the sensors, 15% was found to be most consistent with the true ice edge location. Sea Ice Index V1 applied this 15% ice concentration threshold twice when computing the monthly average gridded fields. The threshold was applied first to the daily gridded concentration; any grid cell with a concentration less than 15% was set to zero. After the monthly average of those daily grids was determined, the 15% threshold was applied again to define the outer limit of that month's ice. Area and extent data values were calculated from this monthly field. Applying the threshold twice made these values smaller than they would have been with the threshold only applied once. This was updated in V2 so that the threshold is only applied to the monthly data after the gridded average has been computed from the daily data.	Final Monthly Data NRT Monthly Data

Satellite transition period adjustment	Satellites, and the instruments that they carry, have a variable but finite lifespan. To create the more than 30-year long Sea Ice Index time series, data from sensors on several satellites over different periods along the time series must be linked together to create the full time series. When a transition from one satellite to another occurs, the monthly average should be computed using data from the first satellite, up to the day of transition, and then data from the second satellite, for the rest of the month. Following a review of the processing code for Sea Ice Index V1, it was found that monthly averages, which included data during a satellite transition period, were being generated from the new satellite and not including partial data contributions from the preceding satellite. For months where these transitions occurred, July 1987, December 1991, and May 1995, the V1 monthly averages were not computed with a full month of data. This was corrected in V2, and the monthly gridded averages are now created from all available data. In addition, the every-other-day SMMR data are now counted twice so that they have the same weight as the daily SSM/I data when they are averaged over the transition month in 1987.	Final Monthly Data
Fractional rounding errors	Sea Ice Index V1 was found to have several instances of fractional rounding errors in the computation of both the daily and monthly data that affected the second decimal place of some of the monthly extent and area values and was negligible in the daily values. These were corrected in V2.	Final Monthly Data Final Daily Data NRT Monthly Data NRT Daily Data

June 2016: Sea Ice Index Resumes Processing with F18 Satellite

On 05 April 2016, the vertically polarized 37 GHz (37V) channel of the DMSP-F17 SSMIS instrument began yielding compromised brightness temperature data. This channel is one of those used to estimate sea ice concentration shown in the Sea Ice Index, so data processing was temporarily suspended.

The Sea Ice Index now uses DMSP-F18 SSMIS beginning 1 April 2016. These sea ice concentration values come from the Near-Real-Time DMSP SSMIS Daily Polar Gridded Sea Ice Concentrations product. For the transition from the F17 SSMIS to the F18 SSMIS, NSIDC investigated calibrating the algorithm tie-point values to minimize the difference between sea ice extents derived from F17 to that from F18. This was done over a 12-month period from 01 March 2015 through 29 February 2016 when both instruments were operational. It was found that the current F17 tie points provided the best match in sea ice extent, so no adjustment to the tie points were needed for F18. The average difference between F18- and F17-derived sea ice extents for that time period is approximately -20,000 sq km. For more information about these

tie points, see the Error Sources section of the Near-Real-Time DMSP SSMIS Daily Polar Gridded Sea Ice Concentrations documentation.

8.3.3 2015

March 2015

The Sea Ice Index processing was updated to use the smaller SSMIS Arctic Pole Hole instead of the SMM/I Arctic pole hole, and the erroneous use of the SMMR Arctic pole hole in SSM/I and SSMIS data was also corrected. See the Correction in Application of SMMR Arctic Pole Hole for Daily Data section for more information. In addition, a new residual weather climatology mask was applied to the Northern Hemisphere that better represents where ice will and will not be. See the Valid Ice Masks section for more information. The extent values in the Daily Sea Ice Extent Data Files have been rounded to three decimal places instead of six because that is the precision of the data. The entire time series was reprocessed and now reflects these changes.

During 2015, approximately 300,000 users visited the site.

8.3.4 2014

September 2014

The daily portion of the Sea Ice Index was updated for 14 September 1984 and the monthly portion was updated for September 1984 due to an error found in the input data source. This caused the daily extent number for that day to change from 7.40367 million km^2 to 6.46729 million km^2 for the Arctic and 18.17876 million km^2 to 18.29700 million km^2 for the Antarctic. It caused the September monthly extent value to change from 7.17 million km^2 to 7.11 million km^2 and from 18.66 million km^2 to 18.65 million km^2 for the Arctic and Antarctic, respectively. The correction did not cause a change in the 1981-2010 average, reported to the nearest 10,000 square kilometers. For more information on the error in the input data, see the Processing History section of the Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-SSMIS Passive Microwave Data user guide (NSIDC-0051).

During 2014, approximately 312,000 users visited the site; and in September of 2014, specifically, approximately 32,500 users visited the site.

March 2014

The citation for this data product was changed from
Fetterer, F., K. Knowles, W. Meier, and M. Savoie. 2002, updated 2009. Sea Ice Index. [indicate subset used]. Boulder, Colorado USA: National Snow and Ice Data Center. http://dx.doi.org/10.7265/N5QJ7F7W.

to the following:
Fetterer, F., K. Knowles, W. Meier, and M. Savoie. 2002, updated daily. Sea Ice Index. [indicate subset used]. Boulder, Colorado USA: National Snow and Ice Data Center. http://dx.doi.org/10.7265/N5QJ7F7W.

The change was made to address the fact that the Sea Ice Index is a near-real-time, ongoing data set that has new data added to it every day.

8.3.5 2013

The following improvements occurred:

- The reference period for anomalies and climatologies changed from a 22-year period (1979-2000) to a 30-year period (1981-2010). A page of supplemental information was published about this change: Baseline Period Change.
- The June mask was updated.
- The SII Web site was redesigned to make it easier to navigate.
- An FAQ page, similar to the one for the MASIE product, was added to the SII Web site.
- Image files are now labeled with data source: NRTSI product or GSFC product.
- The color scheme of trend and anomaly images was changed slightly to make the images easier to interpret.

In July 2013, NSIDC adjusted the ocean climatology mask for June to better filter out erroneous data along the coast and due to weather effects and remove the need for manual Quality Checks (QC). Prior to July 2013, W. Meier would manually QC the data; looking to see if a change in mask would suddenly remove or add ice as the transition from one month's mask to the next happens. This is a possibility for those months in which ice is changing rapidly, because at those times even though the mask is the 1978 to 2001 maximum for a month, the beginning or end of the month might fall outside that maximum on occasion. **Note**: A slight change in the extents and areas for the month of June will occur due to this change in masks, but the change is within the error of the data.

During 2013, approximately 311,000 users visited the site; and in September of 2013, specifically, approximately 34,000 users visited the site.

8.3.6 2012

The daily data files were made available through the Sea Ice Index site in order to meet the needs of users who want the data that are used for the daily chart of sea ice extent. Sea Ice Index documentation was rewritten to give a fuller, cleared explanation of processing.

During 2012, approximately 301,800 users visited the site; and in September of 2012, specifically, approximately 35,400 users visited the site.

8.3.7 2011

During 2011, approximately 266,800 users visited the site; and in September of 2011, specifically, approximately 22,300 users visited the site.

8.3.8 2010

During 2010, approximately 323,400 users visited the site; and in September of 2010, specifically, approximately 27,600 users visited the site.

8.3.9 2009

The site was redesigned. Images could now be displayed on NASA's Blue Marble view of the Earth, and the chart of daily ice extent values was included as a Sea Ice Index product. Before this, it had appeared on the ASINA site only. Walt Meier and Matt Savoie were added to the data product citation in recognition of their role effecting this change. In June, we transitioned from the DMSP-F13 SSM/I instrument to the DMSP-F17 SSMIS instrument.

During 2009, approximately 320,000 users visited the site.

8.3.10 2008

During 2008, approximately 319,800 users visited the site; and in September of 2008, specifically, approximately 47,400 users visited the site.

8.3.11 2007

Arctic Sea Ice News quickly grew in popularity, sending many new users to the Sea Ice Index site. We improved the way the Sea Ice Index processing code worked within the larger passive microwave data processing environment operated by the NSIDC DAAC and interacted with the Arctic Sea Ice News team so that Sea Ice Index products would support that site. NSIDC senior software developer Matt Savoie and ASINA lead scientist Walt Meier led this work and were added to the Sea Ice Index product citation.

During 2007, approximately 108,900 users visited the site; and in September of 2007, specifically, approximately 17,900 users visited the site.

8.3.12 2006

The color bar for the concentration anomaly and trend images was changed from rainbow to shades of red (positive anomalies and trends) and blue (negative anomalies and trends), in keeping with best practices for graphically presenting maps of these types of data. NSIDC project lead Lisa Ballagh made extent maps for September and March (months of minimum and maximum extent) available in kml format, for use with Google Earth and other virtual globes.

The NSIDC Science Communications group published Arctic Sea Ice News 2006. This "ice blog" was created to help manage increasing media attention. It became a regular feature and is now called Arctic Sea Ice News and Analysis (ASINA). The ASINA science team needed to show how Arctic-wide ice extent was changing as the summer melt season

progressed, so they used the daily NRTSI gridded ice concentration fields to obtain ice extent values for the ASINA summer melt season graph, updated daily.

At that time, the daily NRTSI fields were a by-product of Sea Ice Index processing. They were used to create the most recent monthly extent and concentration fields as well as the extent and area numbers but were not retained by the Sea Ice Index. The reason for this is that the Sea Ice Index focused on tracking changes in sea ice that are climatologically significant. To do this, a long, consistently processed record is needed. Satellite passive microwave provides that record, but only when concentration fields are averaged over a month. Day to day variability in the ice concentration record can be the result of short-term weather, of imperfect algorithms, and of sensor problems.

During 2006, approximately 67,000 users visited the site; and in September of 2006, specifically, approximately 8,600 users visited the site.

8.3.13 2004

The SMMR record was added, extending the record back to 1978. To accomplish this, we needed to adjust our near-real-time passive microwave ice concentration data stream to be consistent with the1978-2002 record (a standard product from GSFC). This required adjusting algorithm tie points. Ken Knowles led this work, as well as that of building the Sea Ice Index processing system into a new operational environment at NSIDC. In September of 2004, approximately 2,500 users visited the site online.

8.3.14 2003

We automated the task of updating the site every month and began archiving images and tables of ice extent. NSIDC developer Julia Collins modified the Web Image Spreadsheet Tool (WIST, now the BIST), to work with Index images. The WIST, developed by NGDC's Geospatial group, makes displaying images in tabular form easy and intuitive.

8.3.15 2002

The Sea Ice Index prototype site was published online. It only used SSM/I data, for which the record began in 1987. Anomalies were shown using a base period of 1988-2000.

8.4 Version History

Table 15 describes the version history of the SII product.

Table 15. Version History

Version	Release Date	Description of Changes
3.0	October 2017	Updated the method used to calculate the monthly average sea ice extent and area data values. For more information see the October 2017 product history update.
2.1	January 2017	Summary of major changes: • IDL code ported to Python • New look for images and graphs • New FTP directory structure • Fixed a number rounding errors and updated a some monthly data computations For more information, see Table 13 in the January 2017 product history update.
2.0	July 2016	Summary of major changes: • Now using version 1.1 of GSFC input data • Adjusted redundant 15% sea ice concentration threshold • Adjusted satellite transition period • Fixed fractional rounding errors For more information, see the Table 14 in the July 2016 product history update.
1.2	March 2015	Summary of major changes: • Added the SSMIS Arctic pole hole mask to data from 01 January 2008 to present • Corrected erroneous use of SMMR Arctic pole hole mask in SSM/I and SSMIS data for July 1987 to present. • New residual weather maximum extent masks for Northern Hemisphere applied to entire time series. • In the daily extent file, now rounding to three significant figures instead of six because anything further than three digits is outside the precision of these data.
1.1	July 2013	Replaced the 22-year base period with a 30-year period. All data were reprocessed to take these changes into account.
1.0	July 2012	Made daily images and data available from the Sea Ice Index web site.
1.0	2002	Initial release of Sea Ice Index. Uses version 1.0 of the GSFC product.

8.5 Acknowledgments

Distribution of the data set from NSIDC is supported by the NOAA@NSIDC Team with funding from NOAA and with assistance from the NSIDC NASA DAAC. This site is maintained with assistance from the NSIDC NASA DAAC.

9 Document Information

9.1 Document Author

A. Windnagel

9.2 Document Creation Date

October 2008

9.3 Document Revision Date

- **October 2017:** A. Windnagel updated the document to reflect Version 3 updates.
- **September 2017:** A. Windnagel migrated this document from HTML to PDF.
- **May 2017:** A. Windnagel updated the document to reflect the addition of the median sea ice extent line to the monthly and daily concentration images. This included updating the data processing flow charts (Figures 1-3).
- **April 2017:** A. Windnagel updated the document to describe the new GeoTIFF format.
- **January 2017:** A. Windnagel updated the document to reflect the new Version 2.1 Sea Ice Index and Python code change.
- **July 2016:** A. Windnagel updated the document to reflect the new Version 2 Sea Ice Index.
- **June 2016:** A. Windnagel updated the document to reflect the transition from the F17 satellite to the F18 satellite and added a section on algorithm tie points in section 6.
- **March 2015:** A. Windnagel updated the document to reflect the new Arctic pole hole, new northern NIC Valid Ice masks, and the change to three significant digits in the daily extent file.
- **September 2014:** A. Windnagel added an Errors and Updates section.
- **October 2013:** A. Windnagel updated figures 1-4 to reflect that GSFC daily data is used to create an intermediate final SII monthly product. Previously, the documentation erroneously said that the monthly portion of the GSFC product (NSIDC-0051) was used.
- **September 2013:** A. Windnagel updated the Arctic portion of Table 2 in the baseline-change.html document because the month labels were off by six months.
- **June 2013:** A. Windnagel updated the document for the new 30-year (1981-2010) base period. Updated documentation for the new June ocean climatology mask used to filter weather effects.
- **February 2013:** A. Windnagel added text about the addition of the data type label.
- **July 2012:** A. Windnagel and F. Fetterer updated documentation to cover daily processing and added a product history section.
- **May 2012:** A. Windnagel did a major revision of this document for clarity. Items updated are image descriptions and processing as well as putting the text into the new guide doc template.
- **October 2011:** A. Windnagel added a table containing the time period each instrument is used. This was done in response to the F-17 Goddard final data that has now been processed.
- **March 2011:** A. Windnagel added information on how the shapefiles are created.
- **April 2010:** A. Windnagel doing a full review/revision of this document.
- **June 2009:** A. Windnagel added note about transition from F13 to F17.
- **October 2008**: D. Miller took documentation from the Sea Ice Index Web site and consolidated it into a formal Sea Ice Index guide document.

10 Appendix 1: Data Flow Diagrams

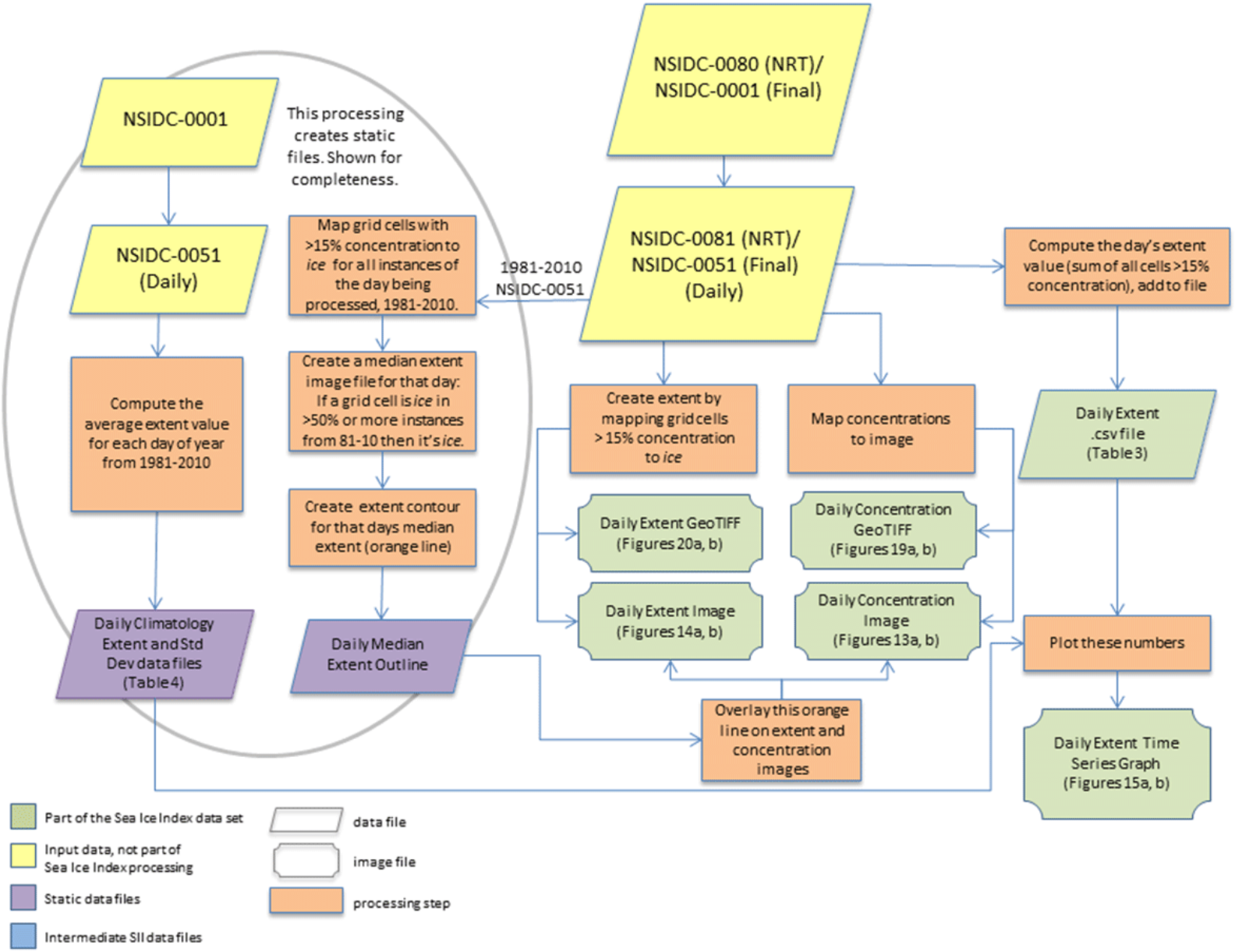

Figure 24. Sea Ice Index Daily Product Processing Flow Chart

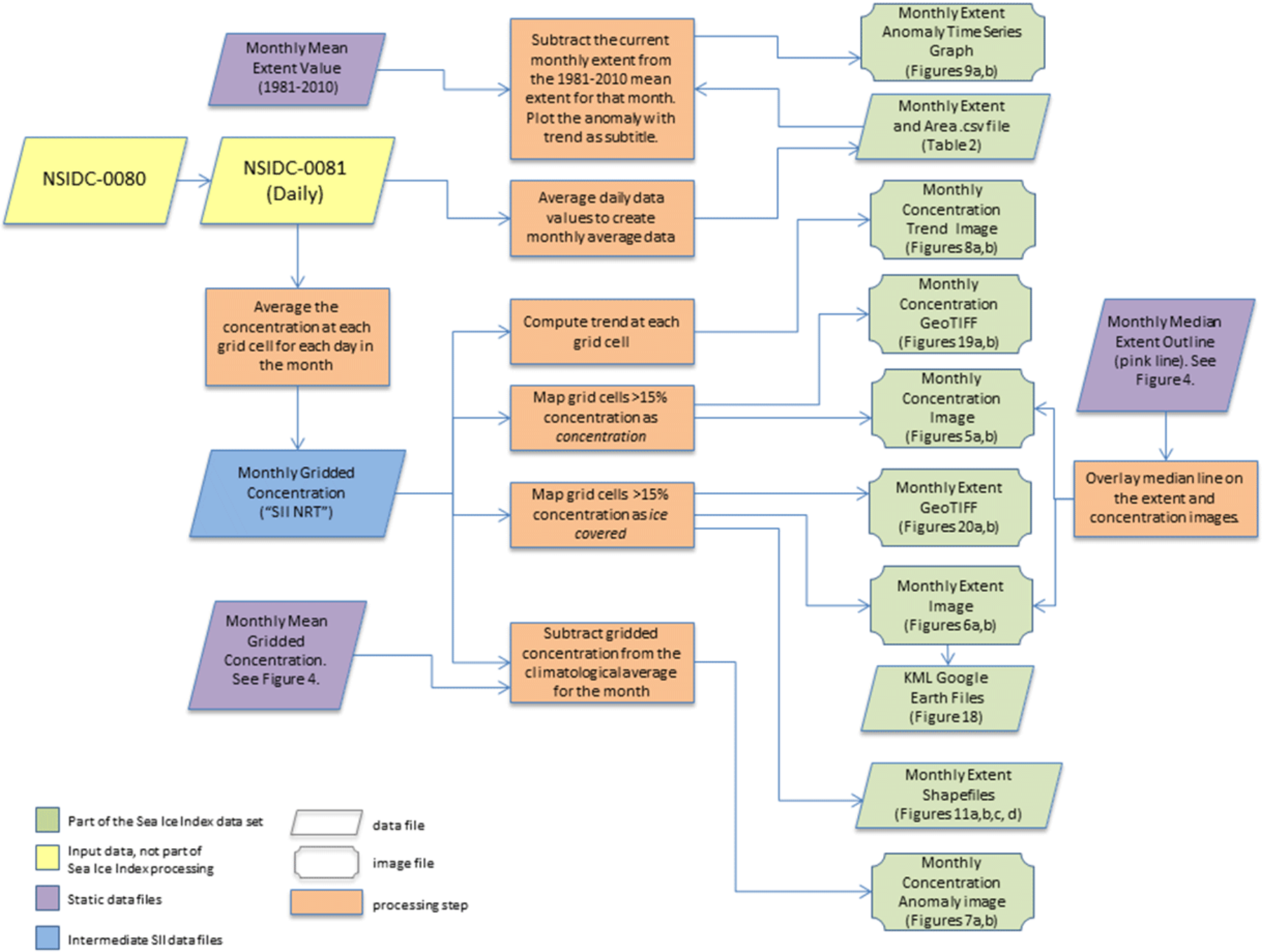

Figure 25. Sea Ice Index Monthly Product Processing Using NRTSI Product

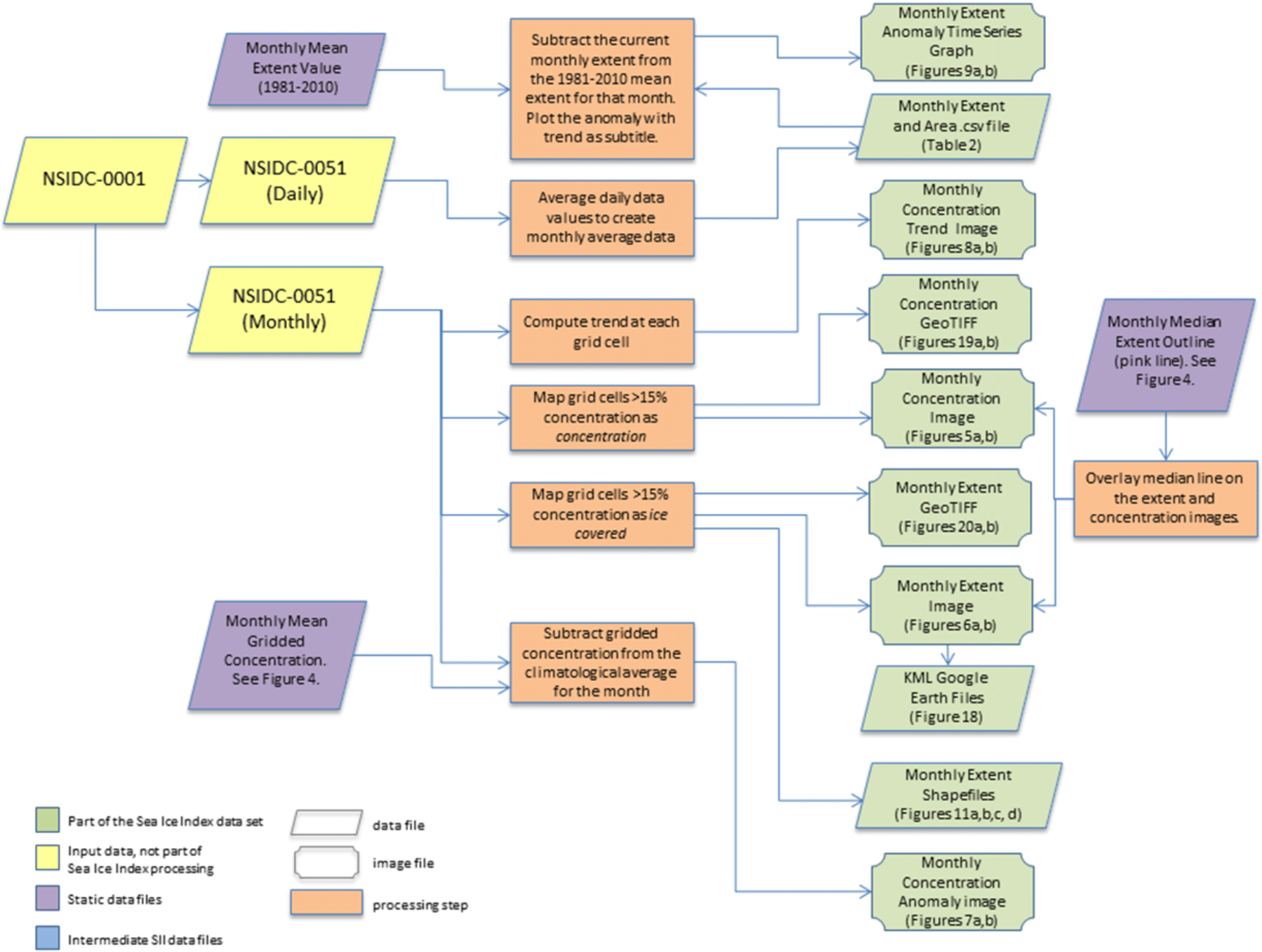

Figure 26. Sea Ice Index Monthly Product Processing Using GSFC Product

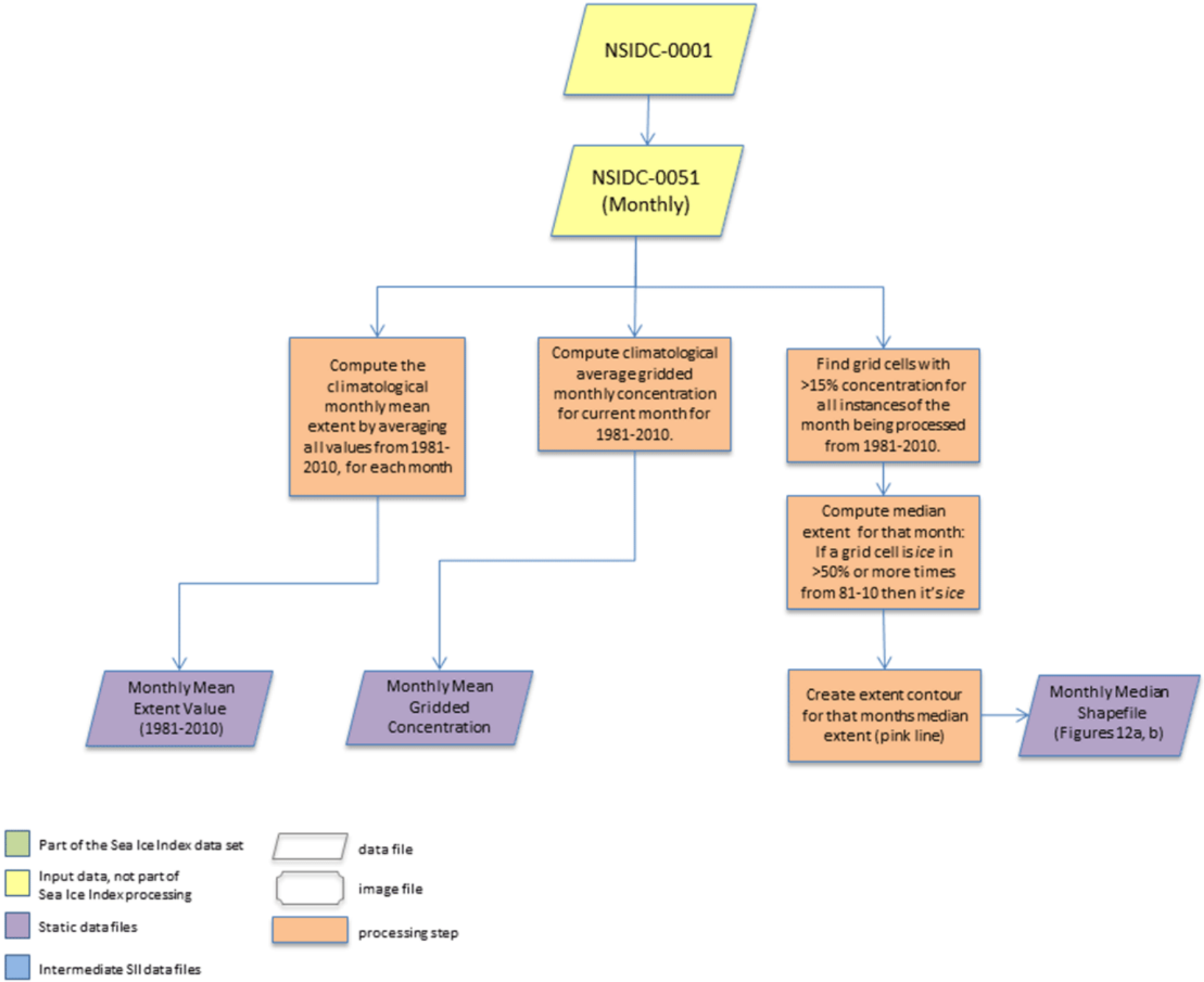

Figure 27. Sea Ice Index Processing for 1981-2010 Median and Means